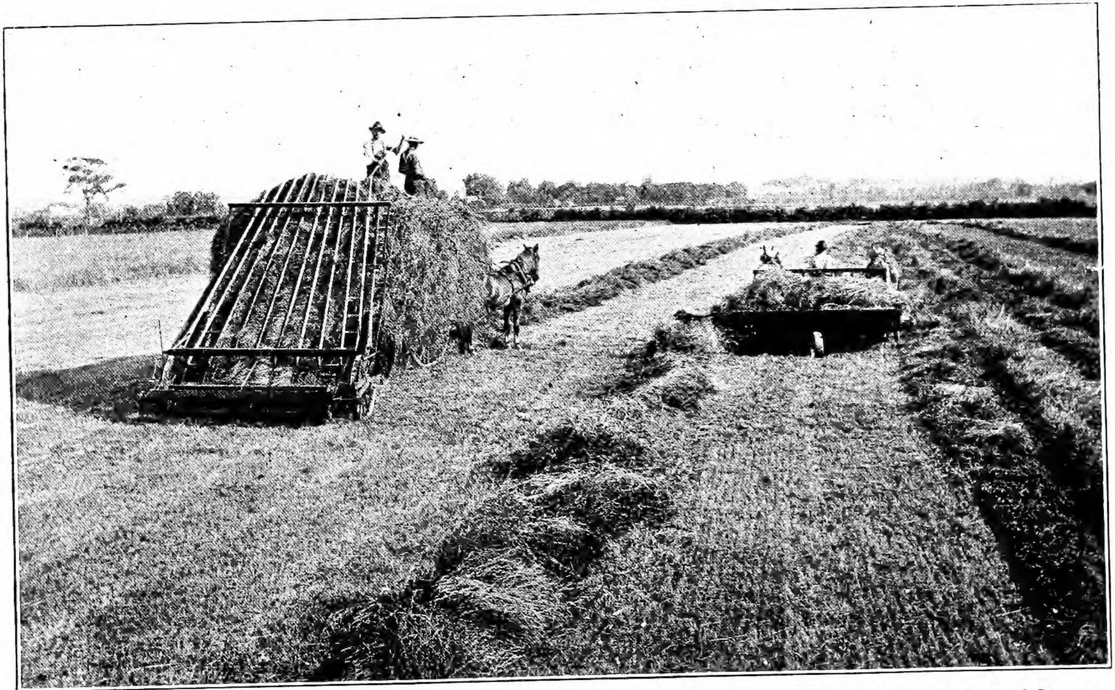
FIELD MANAGEMENT AND CROP ROTATION

EDWARD C. PARKER



Haying with modern machinery. *Photo by courtesy Deere and Company*

Field Management

and

Crop Rotation

PLANNING AND ORGANIZING FARMS; CROP ROTATION SYSTEMS; SOIL AMENDMENT WITH FERTILIZERS; RELATION OF ANIMAL HUSBANDRY TO SOIL PRODUCTIVITY; AND OTHER IMPORTANT FEATURES OF FARM MANAGEMENT

— BY —

EDWARD C. PARKER

Formerly Assistant Agriculturist, Minnesota Agricultural Experiment Station; Special Agent, Bureau of Statistics, U. S. Department of Agriculture, and Agricultural Expert with the Government of Manchuria

1920
WEBB PUBLISHING CO.
ST. PAUL, MINN.

PREFACE

This book has been written with the hope that it will prove of wide usefulness as a textbook in agricultural schools and colleges; as a handy reference book for editors, publicists, and agricultural students; and as a popular treatise for farmers. It treats, in popular language, of the most important problem of modern times—the maintenance of soil productivity and the profitable use of capital and labor in agriculture— a problem worthy of much consideration by the American people in these days of high costs, diminishing agricultural exports, and increasing population.

Field management and crop rotation, as presented in this book, had their inception, so far as the author is concerned, in the class rooms of the Minnesota School of Agriculture under the tutelage of Professors Willet M. Hays and Harry Snyder. In large measure the subject matter of this book traces back to the investigational work of these men as well as to their classification of knowledge about field management and crop rotation. Furthermore, this book is the outgrowth of the author's own experience in crop rotation investigational work at the Minnesota Agricultural Experiment Station, in teaching crop rotation and the planning of farms to students in the Minnesota School and College of Agriculture, as well as in the surveying and platting of Minnesota farms in connection with the gathering of cost statistics and farm management data by the Minnesota Agricultural Experiment Station and the United States Department of Agriculture. Travel and observation of farming practice in many regions of the United States of

America, as well as in Japan, Korea, North China and Manchuria, have also had an influence on the author's presentation of the subject.

The author acknowledges that in this book there is a free use of many ideas and principles taken from Snyder's "Soils and Fertilizers" and "Chemistry of Plant and Animal Life," and also a free use of the ideas and principles relative to soil amendment with fertilizers as advocated by Dr. C. G. Hopkins in the bulletins of the Illinois Agricultural Experiment Station. The investigational work of these men is so important to a discussion of field management and crop rotation that no book on this subject would be complete without it.

Acknowledgment is made to Andrew Boss, Chief of the Division of Agronomy and Farm Management, and to A. D. Wilson, Director of Agricultural Extension and Farmers' Institutes, of the Department of Agriculture, University of Minnesota, for important suggestions and for correcting copy, also to F. J. Alway, Chief of the Division of Soils of the Department of Agriculture, University of Minnesota, for valued suggestions. Many other agricultural writers and Experiment Station workers have given valued assistance in securing local facts about crop rotation plans.

The problems and practicums of this book have been prepared with the idea of calling attention to many of the important features of the text, and also to provide supplementary work relative to the subject matter. Where time permits, the problems demanding supplementary reading will be found of great value. The practicums, if carried out under local conditions, will add greatly to the students' interest in the subject.

The responsibility for the arrangement and presentation of the subject matter, as well as for the interpretation of

much of the investigational data, is with the author. The greatest possible care has been used by the author, as well as the publishers, to avoid error and the omission of valuable facts, and yet it is possible that errors or important omissions exist in the text. The author requests that he be apprised of any that may come to the attention of readers.

EDWARD C. PARKER.

St. Paul, Minn., February 4, 1915.

CONTENTS

PART I—HISTORICAL REVIEW

PART II—ROTATIONS AND PLANS

PART IV—EXPERIMENTAL EVIDENCE

PART V—REVIEW OF SOIL PRODUCTIVITY

PART VI—ADDITIONAL FEATURES

APPENDIX

Compendium of Facts and Statistics

FIELD MANAGEMENT

AND

CROP ROTATION

PART I

HISTORICAL REVIEW

Early Experience of Mankind in Agriculture. The evolution of agriculture among the various nations of the earth has proceeded along very similar lines since the dawn of history and, doubtless, for many centuries of the prehistoric age. Indeed such pioneer agriculture as exists in the twentieth century A. D. in portions of North America, South America, and Africa, closely resembles, in many particulars, the agricultural experiences of mankind in the earliest periods of history. The growing of food crops on cultivated land has never been the first plan of a tribe or pioneer community of men to satisfy their food requirements. Man's first recourse to obtain food has ever been the wild animals of the forest or plain, the fish of the lake or stream, supplemented by the roots, grains and fruits that nature yielded unaided. Sometimes the wild meat and fruits would

NOTE: Acknowledgment is here made to three treatises on the historical features of agriculture from which the author has freely drawn for the material of this part: Roman Farm Management, or treatises of Cato and Varro, translated by Fairfax Harrison, a Virginia Farmer; English Agricultural Writers from Sir Walter of Henley to Arthur Young, 1200-1800 A. D., by Donald McDonald; Historical Sketch of American Agriculture by T. N. Carver, Vol. IV Bailey's Cyclopedia of American Agriculture.

be supplemented with a cultivated cereal grown on small patches of virgin soil, but, even then, the main food reliance was the wild animal life of the country. The families and tribes were more or less migratory. Nature fed them and they wandered from one hunting or fishing ground to another.

As population increased, nature's supply of easily obtained food decreased. Then we find man taming and domesticating animals and guarding their young from the attacks of wild beasts that he might control his meat supply and increase it according to his needs. With his flocks and his herds he now sought the richest grazing lands for his habitation. Life was still migratory to a large extent, but not so much so as when entire dependence was placed on the natural supplies of food. Man had then become skilled as a shepherd or drover. He still hunted and fished, but the hunter had mainly given way to the flock-master and the cattle-drover.

In the early history of mankind, as well as in the agricultural history of many modern communities, the pastoral or grazing stage of animal husbandry was slowly merged with agriculture. Agriculture—the growing of food crops on cultivated land—originated from several causes, chief of which was the desire for a varied diet, the need of winter forage for live stock, and the ever increasing population that demanded more food supplies from the known regions of the Earth than could be supplied from hunting, fishing, and grazing live stock. And so man chose from the wild plant life surrounding him the cereals and vegetables that best suited his taste, and the grasses and forage plants that produced most abundantly, and began to grow these crops on cultivated land where he could nurse and protect them as he had once learned to tame and protect the wild

animals of his environment. Early agriculture did not displace the grazing of live stock, but merged with it. Animal husbandry came to rely more and more on the products of the cultivated fields to winter and fatten the animals. As long as two thousand years ago the farm breeding and feeding of live stock, as distinct from pastoral animal husbandry, was well developed among the Romans, and this same evolutionary process has taken place in the development of nearly all the agricultural regions of the Earth.

It was early learned that cultivated lands under crop gradually lost their producing power. When cultivated land lost

From Painting by Rosa Bonheur.
Plowing with oxen in Europe.

some of its producing power, it was abandoned to nature, and new land of virgin fertility was reclaimed from the forest or prairie. This was the natural and simple procedure under the circumstances. Rich, productive, virgin land was abundant and cheap. Labor was relatively scarce. There was little knowledge of the causes for the decrease of soil productivity or the methods for renovating worn out land, and so the farmer followed the lines of least resistance and aban-

doned the old land for new. This custom of abandoning partly worn land has been almost universal in the history of all nations and their agriculture. The English farmers of the eleventh to the fifteenth centuries grew considerable grain, and the preparation of virgin land every year was a regular part of the farmer's work, some of the old land being allowed to go back to grass or weeds every year. Early agriculture in the American colonies followed the same practice. The tobacco growers of old Virginia would clear virgin land, plant tobacco for three to eight years on it, and then abandon the land to nature. Agricultural communities in South America, Central America, and even North America may still be found where this practice is followed.

The Early Use of the Bare Fallow. Along with such agricultural experience as taught man that cultivated lands under crop soon lost their producing power came the knowledge that idle lands tend to recuperate their power to produce good crops. The experience of the farmers of many nations in many climates showed that idle, abandoned land would come back in its productivity. In man's early discovery of this principle we find the origin of the practice of "bare fallowing." As land became scarcer and as agriculture increased in importance the bare fallow became a systematic feature of agriculture. Instead of working land to a condition of unproductivity and then abandoning it to nature, the farmer cropped the land continuously with regular fallow periods every second or third year.

The bare fallow was the basis of Roman agriculture for a long period, being systematically alternated with the field crops every second or third year. The English farmer of the thirteenth to the seventeenth centuries also placed a great deal of dependence on the bare fallow in his scheme of cropping. Writing in the early part of the seventeenth century and just

prior to the spread of knowledge about clover in England, the Rev. John Laurence says: "Fallowing kills weeds by turning their roots to the air. It lays the land in ridges thereby better exposing it to receive the nitrous influence of frost, wind, sun and dew. These influences all tend to sweeten and mellow the land." Many agricultural regions of the United States of North America have made extensive use of the bare fallow in their methods of agriculture—in fact the bare fallow, as a method for increasing the productivity of land, may still be found in numerous agricultural regions of North America.

Modern agricultural science reveals the fact that, while the bare fallow acts as a temporary stimulus to soil productivity, it is a practice that serves to hasten the ultimate unproductivity of a soil area. The green manure fallow, the annual pasture, and the legume meadow are the modern methods for "resting land," and the old bare fallow is disappearing except as a means for destroying noxious weeds and, in some regions, for conserving soil moisture.

Legume Crops in Agricultural History. While modern science has answered all the whys and wherefores about the bare fallow, the green manure legume crop, and the legume meadow crop, in their relation to soil productivity, the practices of green manure fallowing and seeding down land with legume crops did not originate in modern times. The value of the legume crop as a soil renovator was known many centuries before science discovered all the reasons why legume crops rest the land more than a bare fallow. In fact, the green manure fallow and the legume crop meadow came to supersede the bare fallow in Roman and English agriculture long before the scientific facts were known about legume crops and the nitrogen gathering bacteria or the function of humus in the soil. Early experience with legume crops, therefore, developed the art of rotating them with other field crops.

Two thousand years ago the Romans well knew that the seeding of lupines, beans and vetches on their cultivated lands greatly increased the yields of succeeding grain crops. Discussing the best plants for the Roman farmer to cultivate, Varro wrote, fifty years before Christ: "Field beans should be sown as much as possible in your corn land." Varro also wrote about green manure crops in a manner that needs no revision to-day. He says: "Certain plants are cultivated not so much for their immediate yield as with forethought for the coming year, because, cut and left lying, they improve the land. So, if land is too thin, it is the practice to plow in for manure lupines not yet podded, and likewise the field bean, if it has not yet ripened so that it is fitting to harvest the beans."

Alfalfa was one of the standbys of ancient agriculture. It was brought into Europe from Asia long before Christ and gradually spread all over Europe. It had become a standard farm crop in Roman agriculture about the time of Christ. Columella, a Roman author, writing about alfalfa in the early Christian era, says: "But of all the legumes, alfalfa is the best, because, when once it is sown, it lasts ten years; because it can be mowed four times and even six times in a year; because it improves the soil; because all lean cattle grow fat by feeding upon it; because it is a remedy for sick beasts; and because two thirds of an acre of it will feed three horses plentifully for a year." Columella gives instructions about seed bed preparation, seeding, care of the new seeding, and methods for feeding, that can hardly be improved to-day.

Clovers, trefoil, and alfalfa were introduced into England from Spain, France and Flanders in the first part of the seventeenth century. About the middle of this century many observing writers began to discuss the public loss that arose from constant pasturing on one portion of the land and con-

stant plowing and fallowing on another portion of the land. After the introduction of legume crops into England the benefits to succeeding grain crops from the use of legumes became quite well known. The practice of seeding legume crops with a nurse crop of grain developed during this period, and the rearing of cattle on arable land received a great impetus. Animal husbandry and grain growing were merged in England during this period largely because farmers discovered that

Plowing in North China with a steel pointed wooden plow. The topsoil is not inverted but merely cultivated into ridges.

legume crops yielded much more hay and pasture than their native grasses, as well as that they improved the productivity of arable land better than the bare fallow.

The prevalent ideas about legume crops in the middle of the seventeenth century in England are well illustrated by the writings of Andrew Yarranton, who, in 1663, wrote a book encouraging the growing of clover, entitled, "Great Improvement of Lands by Clover." He says in this book: "Six acres of clover are as good as thirty acres of natural grass for fattening cattle." "Clover doth so frame the land that,

being plowed, it will yield three or four years together a crop of wheat, and after that, a crop of oats." "Clover improves land by the roots' cleaning the soil, and by the shade of the leaves, beneath which an incipient decomposition is encouraged which mellows the surface of the ground and provides food for future crops." "Lime should be used to encourage the growth of clover."

Clover was the first important legume crop to be introduced into the United States of North America. It was introduced from England into the New England colonies in 1763. In the period 1790 to 1810 clover first began to have some importance in American agriculture, and was frequently used in rotation with grain in Pennsylvania and New York as a substitute for bare fallow. The use of legumes in American agriculture has not yet become widespread. The development of the great cotton growing industry in the Southern states in the years 1830 to 1860, the rapid extension of cattle and sheep grazing in the Western states in the years 1865 to 1885, and the rapid development of specialized wheat and corn culture on the extraordinarily fertile prairies of the Middle Western states in the years 1870 to 1890, built up three great special industries that have not yet given way entirely to the mixed type of farming with the use of legume crops and the rearing of live stock in connection with the special enterprise. The use of legume crops in American agriculture is on the increase, however. Progressive grain, corn, and cotton growers are fast learning that clover, alfalfa, cowpeas, soy beans, or some other legume is a necessity in any rational scheme of cropping that will maintain soil productivity. The American live stock feeder is also fast placing his chief dependence on the legume crops for fodder crops on account of their productivity and high nutritive value. The United States Department of Agriculture has literally

combed the Earth to find legumes adapted to every soil and climate of the United States and to every need of farm management. As a result, the most profitable and productive legume crops of all nations and all climates have been brought to the United States, and the future will undoubtedly see a great increase in the use of legume crops in American agriculture.

It was not until 1888 that scientific investigators discovered the relationship that exists between legume crops and the nitrogen gathering bacteria (See page 57). This discovery cleared up the mystery of why legume crops had such unusual power as soil renovators, especially when used for green manure fallows. It settled for all time the hitherto vexed problem of nitrogen plant food in agricultural soils, for it showed that the legume crop, and the nitrogen gathering bacteria associated with it, were the farmer's key to an absolutely inexhaustible supply of nitrogen in the atmosphere. It also proved that the legume crop meadow or green manure was eminently superior to the bare fallow as a means for maintaining the productivity of the soil (See page 350). Scientific investigation since 1888 has added much to our knowledge of the soil bacteria associated with legume crops and of the methods that can be employed to inoculate soil with these bacteria so as to stimulate legume growth. (See page 415).

There is much that we may still learn about legume crops and their place in a permanent scheme of agriculture, but we know enough now to realize the unrivaled value of these crops as soil renovators. The Romans realized the value of these crops in relation to soil fertility two thousand years ago, and when one sees the thousands of acres of cotton, corn, and wheat in the United States still grown in a ruinous system of continuous cropping, one wonders if the Romans were not

wiser farmers two thousand years ago than we are to-day in the twentieth century after Christ.

The History of Soil Tillage Methods and Implements. The tillage methods employed in the agriculture of ancient and medieval times were crude in comparison with the best tillage methods of modern times. The farmer of early times did not have at his command the steel moldboard plow, the disk harrow, the sub-surface packer, and the deep tillage plow, with which to invert and pulverize his soil easily and thoroughly. The plows employed in agriculture, prior to the middle of the nineteenth century, were crude and inefficient. As compared with the thorough pulverizing

Photo by courtesy "The Farmer."

In the disk harrow the modern farmer has an implement for smoothing and fining the seed bed, closing air spaces in freshly plowed land, and killing noxious weeds, that is far more efficient than any implement available to the farmer of ancient and medieval times.

work of the modern plow they merely stirred the surface soil. Many of the earliest plow types were merely sharpened, hardened sticks of wood. Later, an iron point was attached. The ancient and medieval farmer usually ridged his land in order to form a seed bed of loose soil. Often the tillage was accomplished as much with the mattock and spade as with the oxen or horse drawn plow. Hand tillage was common in Roman and English agriculture, and was largely employed in the early days of colonial agriculture in North America. In the Virginia colony, which was mainly agricultural, there were but one hundred and fifty plows of any kind in use in 1649, the majority of the fields being hand tilled.

In spite of the tillage implement handicaps under which early agriculture was pursued the Romans learned from long experience the value of deep and thorough tillage. The Roman farmers worked their land deeply, thoroughly, and often. They learned the value of deep tillage in conserving soil moisture and practiced "dry farming" in Mesopotamia for generations.

The value of thorough soil tillage as a factor in crop production was not emphasized and brought completely to the light until the middle of the eighteenth century. The Romans undoubtedly understood the value of thorough soil tillage and practiced it themselves, but with the decay of Rome and of Roman civilization their knowledge of the art of agriculture passed temporarily into oblivion. Many centuries intervened before the European barbarian tribes developed the art of agriculture to a point approximately comparable to that of the Romans in the height of their civilization. English agriculture, for example, underwent all the elementary stages of agricultural evolution from the eighth to the eighteenth centuries, and not until the middle of

the eighteenth century, or even the first part of the nineteenth century, had English agriculture sufficiently advanced to be in any way comparable to the agriculture of the Romans.

In the middle of the eighteenth century an Englishman named Jethro Tull made some discoveries about soil tillage that made his name famous, and that gave a great impetus to the study and practice of thorough soil tillage as one of the most important of all factors in crop production. Before Tull's time English lands were scantily tilled and the seed was thickly sown broadcast. Legume crops had come into quite common use as well as the rearing of live stock on arable land, but the tillage methods were poor and inefficient. During Tull's travels in France he noticed that the vineyards were not manured, but were very thoroughly tilled. This gave him the idea that field crops could be similarly grown without manure, if the soil were thoroughly pulverized. He invented a crude machine for sowing grain in drills that would permit inter-tillage, and he also improved the plows and tillage implements of his time. His experiments and observations showed that drill sowing required less seed than broadcast sowing, and that with inter-tillage the fold of crop from seed was greater than his neighbors were getting by the common methods of sowing and tillage.

Tull's experience led him to develop a theory of crop production which stated that "tillage is manure," and that "hoeing and pulverizing the soil might supersede the use of manure." In the later years of his life he came to realize that his tillage methods were but one important factor of crop production and not inclusive of all the essential factors. For many years, however, he advocated thorough soil tillage as the cure-all for lands of low productivity. Agriculture owes much to Jethro Tull. In his experiments and writing he gave us the first great and comprehensive lesson about

the value of the inter-tilled crop and thorough soil pulverizing in the art of successful agriculture. Other men may have known of the value of these practices in the centuries before his time, but, if so, they failed to stamp their ideas permanently on the art of agriculture. Jethro Tull's ideas soon became incorporated in English agriculture, and, subsequently, in the modern agriculture of many nations. From Jethro Tull we have learned that thorough soil tillage is essential to maximum crop production and that the inter-tilled crop prepares the land for a succeeding crop as well as a bare fallow.

The invention of modern tillage implements is mainly a matter of American history. In 1814 Jethro Wood, of New York, took out the first patent for a cast-iron plow, but it was not very successful. By 1825 the cast-iron plow had received enough improvement so that a number was put

Surface tillage between crop rows leaves the soil in as good condition for the succeeding "grain crop" as the bare fallow, and there is no loss of revenue for one year from the land.

to use in the New England States. John Deere made the first steel plow from an old saw blade in 1837. From that date one improvement after another has followed on the steel plow, until to-day the farmer has a plow that runs easily, cuts evenly and deeply, and that lifts and pulverizes the soil in a manner more thorough than can be attained with hand tillage. The modern plow with its long base, hard but malleable shear, curved moldboard in types adapted to many soils and conditions of plowing, clevis attachments, and rolling coulter, is an implement of modern times only. The plow as we know it to-day is less than fifty years old.

The last quarter of the nineteenth century saw many valuable inventions in tillage implements, such as the disk

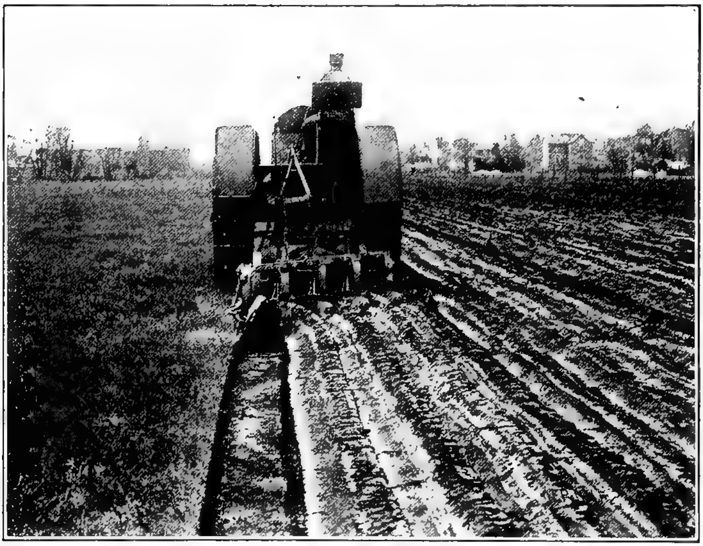


Photo by courtesy Emerson Brantingham Company.
Breaking sod with gas engine power. A distinctive feature of twentieth century agriculture is the application of engine power to farming operations.

harrow, sub-surface packer, riding cultivator for inter-tilled crops, and various types of smoothing harrows, all of inestimable value in the fining and pulverizing of soil. The early part of the twentieth century has seen two notable inventions pertaining to the work of soil tillage, namely, the gas tractor with its engine gang plow, and the disk deep tillage machine. Gas tractor plowing, though now practical, is still in its infancy. The future will undoubtedly show an evolution in the application of power to soil tillage that will give the farmer a new and marvelous control over the tillage of soil. The disk, deep tillage plow of the twentieth century will plow and pulverize types of soil that were difficult to handle properly with the common plow, and where deep tillage is desirable this machine will cut and pulverize the soil to a depth of twelve to eighteen inches, mixing the topsoil with new subsoil or mixing the organic matter of a green manure crop with the soil to a depth of twelve to sixteen inches, and thus, in certain types of soil, greatly enlarging the area in which crop roots can penetrate and absorb plant food.

Not only have modern inventions in tillage implements eliminated all back breaking labor from the work of soil tillage, but also applied all the modern scientific principles relative to soil tillage in their mechanism and operation. Other civilizations learned from experience many of the principles of efficient soil tillage, but none had such power and mechanical facilities to apply these principles as we have who live in the twentieth century.

The History of Crop Rotation. Crop rotation is by no means a distinctive feature of modern agriculture. Many of the principles of rotation cropping were known to the primitive nations. The value of alternating legume crops and fallow years (forerunner of the modern cultivated crop) with

grain crops was known to the Romans one hundred years before Christ. The Romans also understood the value of farm manures as a check to the loss of plant food from the soil, and that the rearing and feeding of live stock on arable land in connection with the growing of food crops gave greater permanency to agriculture than a system of agriculture that did not include live stock. Concerning the relation of animal husbandry and forage crops to agriculture, Varro, the Roman author, writing fifty years before Christ, says: "The practice and the art of the farmer are one thing, I say; that of the shepherd, another; the farmer's object being that whatever may be produced by cultivating the land should yield a profit; that of the shepherd, to make his profit from the increase of his flock; and yet the relation between them is intimate, because it is much more desirable for a farmer to feed his forage on the land than to sell it, and a herd of cattle is the best source of supply of that which is the most available food of growing plants, namely, manure; so it follows that whoever has a farm ought to practice both arts, that of agriculture and that of grazing cattle."

Systematic crop rotation, however, as we now define it, meaning the alternation of the grain, grass and cultivated crops on a certain area of land, was not formulated into a definite practice, commonly employed in agriculture, until the seventeenth and eighteenth centuries. During this age legumes had been introduced into England, turnip culture for sheep feed had become quite common, and the tillage practices of Jethro Tull had been accepted. In the eighteenth century in England, sheep raising and dairying were practiced by many farmers on arable land. Clover and turnips had been largely substituted for the bare fallow, and the forage crops were fed on the farm. The frequent use of the bare fallow, so long a feature of English agriculture, began to be

strongly disapproved by the leaders in agricultural thought who advocated, instead, the continuous cultivation of the land with successions of different crops including clover and turnips.

Systematic rotations were developed during this period, such as (1) turnips, (2) barley, (3) clover, or, (1) wheat, (2) beans, (3) oats. The leases on English lands began to contain rigid cultivation clauses which required tenants to manure land; allowed only two crops to be grown in succession and removed from the land; and stipulated that land sown to clover, if fed off, or with turnips, fed on some part of the farm, were not to count as crops. Leases of this kind show the well defined cropping systems that had grown up in England at this time, which combined legume crops, grain crops, cultivated crops, and annual pastures in a systematic rotation, and which prove that the merging of animal husbandry with agriculture had become an accomplished fact.

Arthur Young, the most prolific of all the early English agricultural writers, whose writing was done in the latter part of the eighteenth century and the first part of the nineteenth, was the first great apostle of mixed farming. He taught the value of legume crops, the use of crop rotation, and the feeding of live stock on the farm with the return of the manure to the land. He insisted that grass land and grazing were of primary importance to English agriculture, and the management of arable land of only secondary importance. Of his writings it has been said: "They produced more private losses and more public gain than those of any other author." In many ways he was a theorist. His own agricultural enterprises often failed and he doubtlessly caused others to fail in the attempted practice of his theories. He, nevertheless, stimulated his people into an awakened agriculture out of which there came definite policies of crop rotation, soil man-

agement, and the relation of animal husbandry to agriculture, that have come down as a valuable heritage to the agriculture of the twentieth century.

By 1840 the practice of crop rotation was almost universal in England, and also the use of artificial manures to supplement animal manures. English vessels were bringing large quantities of guano, rich in phosphorus and nitrogen, to the soils of England. The use of bone phosphate in English agriculture also commenced in the years 1840 to 1860.

Early agriculture in the United States of North America was based mainly on English customs, due to the fact that the early settlers were chiefly English and Scotch. English rotation plans appeared early in the history of American agriculture in the oldest communities where agriculture had advanced beyond the pioneer stage. The old English plans were modified somewhat to suit the new conditions, especially to include Indian maize. One of the earliest used rotation plans in the American colonies was: (1) fallow, (2) wheat, (3) peas or beans, (4) barley. In his letters and papers George Washington describes a good crop rotation plan that he found in use on Long Island in 1790, as follows: (1) corn (manured), (2) oats or flax, (3) wheat (with four to six pounds of clover and one quart of timothy), (4) meadow, (5) pasture. In the years 1800 to 1810 this same Long Island rotation plan, with some slight modifications, came into quite general use in Pennsylvania. In Virginia, prior to 1800, many farmers followed a rotation plan of (1) corn, (2) wheat or oats, and (3) land allowed to grow weeds and grass and pastured. After 1800 in Virginia a rotation plan often used was: (1) corn, (2) wheat (with clover), (3) clover meadow with second crop plowed under, (4) wheat.

The most important principles of rotation cropping are shown in these rotation plans used in England and the Amer-

ican colonies in the first part of the nineteenth century. We have improved but little on these plans in the twentieth century. We have learned more about the use of annual pastures, cover crops, and green manures, as well as the methods for combining these crops with the staple field crops in a rotation plan. We have improved somewhat the English rotation plans of the eighteenth and nineteenth centuries, but the principles of rotation cropping are not new in the history of agriculture. The scientific investigations of the nineteenth and twentieth centuries have explained many of the facts about crop rotation that were known only by experience to previous generations. Modern exploration work also is continuously adding valuable legume and forage crops to fit into cropping schemes for many different climates and systems of farming. Furthermore, modern science has shown us the limits of the potency of crop rotation to secure high crop yields. We now know that the chief value of crop rotation is to keep the reserve plant food of the soil available to crops, and that no amount of crop rotation can add any plant food to the soil except nitrogen. Knowledge of these facts enables the modern student of agriculture to place a correct value on soil tillage, crop rotation, and commercial fertilizers, as factors of crop production.

Crop Rotation an Important Feature of Farm Management. The practice of crop rotation developed chiefly from the experiences of mankind relative to soil productivity. The early history of agriculture and of crop rotation shows that man's chief concern in planning systems of cropping was to maintain soil productivity and avoid the low yields that experience had shown him resulted from continuous cropping. Labor was cheap in the early years of agriculture and but little attention was paid to the economical management of man labor, horse power, and machinery.

The twentieth century has brought labor conditions in agriculture that make the correct management of farm labor, horse power, and machinery, as important a factor in profitable farm management as the maintenance of soil productivity. Farm labor becomes more costly with every passing year, and farm wages are tending to rise to the city wage level for skilled mechanics. At the same time the twentieth century farmer demands more skill of his laborers than the nineteenth century farmer demanded. The modern extensive use of large capacity machinery in agriculture demands skilled laborers, large capital investment, and a relatively large

Photo by courtesy Deere and Company.

The modern American type of steel plow inverts and pulverizes the soil more thoroughly than any tillage implement possessed by the farmer of previous eras, and the gang plow has greatly increased the amount of horse power which one man can control.

amount of efficient horse power on the farm. Under these conditions small leaks in the management of farm labor, horse power, and machinery, may become an important feature in the profit and loss account of a farm. Maximum efficiency of man labor and horse labor is essential to the maximum net profit on the twentieth century farm.

Systematic crop rotation has a very important relation to the efficiency of labor and machinery on farms. The orderly arrangement of fields, and seasonal distribution of farm labor, provided by a well planned crop rotation system, are basic features of good farm management, and essential to the maximum efficiency of farm labor and machinery. Other things being equal, the farm that has its fields laid out in an orderly and systematic scheme of cropping will effect economies in the management of labor and machinery that are not possible in a haphazard scheme of field management or in systems of continuous cropping.

By far the greater part of the scientific evidence relative to the value of crop rotation in farm practice relates to the problem of soil productivity. There are but few scientific data to illustrate and prove the value of crop rotation in the efficient management of farm labor and machinery, but the experience and observations of the best farm managers support the theory of the value of crop rotation in this respect. The new farm management of the twentieth century must recognize the basic importance of a systematic scheme of crop rotation in the successful management of the vast majority of American farms. As the reader of this book peruses the text and the diagrams of Part II the great importance of systematic crop rotation in the general management of a farm will become apparent.

The Effect of Cheap and High Priced Land on Agricultural Methods. The history of all nations shows that cheap,

fertile land has always been accompanied by wasteful, extensive methods of agriculture. Under such conditions it has ever been useless to preach against slothful farming and to advocate crop rotation and all the good farming practices associated with it. So long as land is cheap and virgin fertility abundant it is easier and usually more profitable for the pioneer farmer to increase his profits by increasing his acreage of land than to practice intensive systems of farming. The lure of increasing land values is also a factor in causing men to own and farm large areas of land in a slothful and wasteful manner.

But history also shows that, whenever land begins to lose its virgin fertility and yet become high in price, more intensive systems of farming eventually arise from the force of necessity. Systems and methods of farming, such as continuous wheat growing or cattle grazing, that were profitable on land worth $10.00 per acre, are not profitable on land worth $100.00 or more per acre. High land values are usually accompanied by high market prices for farm products and by a lowered marketing cost; but, on the other hand, the carrying charges on the land and the costs of production rise to a point that more than offsets the price gain and the marketing economies. Profitable farming on high priced land must consider the problem of soil productivity, efficient management of labor and capital, and the choice of crops and systems of farming that will yield large returns per acre under intensive management.

It often occurs, however, that lands, once cheap and very fertile, pass through a generation or two of advancing land values maintaining the same simple, wasteful systems of farming that were in vogue in the days of cheap land. Much of the choice, high priced, prairie land of the Middle West in the United States is farmed to-day by methods that are but

little different from the methods employed when lands were cheap and virgin fertile. Many of these choice old farms would not carry operating expense, taxes, and current interest on a modern valuation, because the system of farming is ill-suited to the present day conditions of soil fertility and market value of the land. The owners of such farms remain solvent only because the present day value of their land is not a real factor in their expense accounts. Many such farms would be in bankruptcy, if interest charges had to be met, as well as taxes and the expenses of crop production.

Successful farming on high priced land from which much of the original store of available plant food has been taken is a problem necessitating serious attention by the man who purchases high priced land and to whom the price of land is a real factor in business. Under these conditions the necessity for crop rotation, thorough tillage, and even soil amendment with fertilizers, is apparent and real, in order to raise and maintain a condition of high productivity in the land. Also the necessity arises for a system of farming that will give the greatest possible efficiency to the farm labor and to the money invested in machinery and equipment, and that will yield crop values commensurate with a high land price.

Crop rotation in itself is not the cure-all for unproductive land or the absolute key to profits from high priced agricultural land. But crop rotation is the chief factor in a combination of good farming practices that will maintain the productivity of the soil, and around which intensive systems of farming may be developed that will yield the maximum crop value per acre at the minimum of expense. Crop rotation is to general field agriculture what the foundation is to the house, the solid base on which we may successfully rear a permanent superstructure designed in a hunderd different ways according to our individual requirements and desires.

PART II

ROTATIONS AND PLANS

CHAPTER I

DEFINITION AND CLASSIFICATION

The term "crop rotation" is used to define a system of growing grain, grass and cultivated crops on a given area of land in such order and succession as to keep the soil productive, in good tilth, free from weeds, in such mechanical condition that moisture for the crops is easily controlled, and so as to insure the productive employment of the farm proprietor's capital and labor. The term "continuous cropping" is commonly used to mean the exact opposite of crop rotation: namely, the growing of any one class of crops, such as the grain, grass or cultivated crops, for many years in succession on the same area of land.

Classification of Field Crops for the Purpose of Studying Crop Rotation. The staple field crops may be divided into six general groups for the purpose of studying and planning systems of crop rotation: namely, grain, grass, cultivated, catch, green manure, and cover crops. This classification is not based on any botanical relationships whatsoever, nor on any similarity of appearance, but on the methods employed in seeding and harvesting the crop, the methods of soil preparation and cultivation, and the purposes for which the crop is grown.

Grain Crops. This group includes such crops as wheat, barley, rye, oats, flax and millet, grown for the value of their seeds. Field peas, wrinkled peas, and soy beans, when sown with a grain drill, and grown for seed production, may also

be included in this group, although they differ materially in their effect on the land as compared with other grain crops. Wheat and rye have varieties that are spring sown and varieties that are autumn sown. These crops are grown in largest quantities in the Northern part of the Temperate Zone, and the usual method of soil preparation is autumn or early spring plowing with thorough harrowing. The modern, almost universal, method of seeding the grain crops is to sow in drills six or seven inches apart with a machine known as a grain drill that mechanically opens the soil and puts the seed in the ground at a uniform depth.

Photo by courtesy "The Farmer."

Seeding the "grain crop" with the grain drill. Drilling the seed is superior to broadcasting, because less seed is necessary, the seed goes in at a uniform depth, and the seed is covered better. "Grass crops" are often seeded with the grain as a nurse crop, either by mixing the seed with the grain in the hopper, or by means of a special grass seeding device on the drill.

Wheat and oats are sometimes sown on land that has not been plowed but merely pulverized to a depth of three or four inches with a disk harrow. In many of the corn growing sections of the United States, land which has grown corn is quite commonly prepared in this manner for the seeding of wheat or oats. When crops are sown very thickly on the land, as grain crops usually are, no cultivation of the soil is possible from seedtime till harvest.

Grass Crops. In this group are included those crops that are most commonly used for pasture and hay to be fed to farm animals, such as timothy, brome grass, redtop, blue grass, red clover, alsike clover, crimson clover, white clover, and alfalfa. The characteristic feature of this class of crops is that they require little or no cultivation, and that during the time they occupy the land a turf or mulch of roots and stems is developed that fills the surface soil with vegetable matter. When the soil occupied by these crops is broken, this turf of roots and stems is mixed with the mineral matter of the soil and gives it a loamy, friable texture that cannot be secured following the growth of either the grain or cultivated crops, unless heavy applications of barnyard manure have been made.

The grass crops are usually sown by either of two methods: (1) the seed is sown with a special grass seeding machine or a grain drill on a thoroughly pulverized seed bed at a time when no other crop occupies the land, and in a season of abundant rainfall or when the subsoil is well supplied with moisture, or (2) the seed is sown with a nurse crop of wheat or barley in the spring season, or sown in the spring on land occupied by a crop of autumn sown wheat or rye. If sown with spring wheat or barley, the grass seed is mixed with the grain seed in a grain drill and drilled into the soil along with the grain seed, or, if seeded with autumn sown wheat or rye,

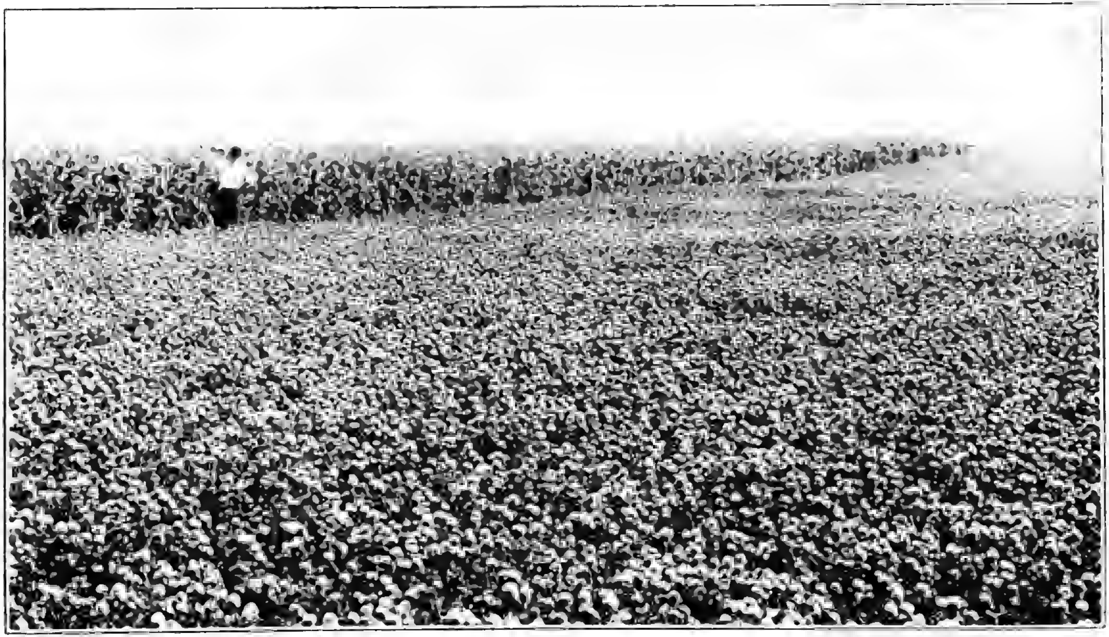


Photo by courtesy "The Farmer."

Medium red clover—the most widely diffused legume meadow crop in the United States. The hay is highly nutritious, the crop fits into many kinds of rotation plans and will add humus and nitrogen to the soil.

it is scattered on top of the soil with a special grass seeding machine where the grain crop was sown and then harrowed in.

Seeding grass crops with a nurse crop of grain is a more practical method, wherever it is possible, than seeding the grass crop alone in the spring season, for, when the nurse crop is sown, the land produces a crop of grain while the grass crop is getting started; whereas, if the grass crop is sown in the spring season without a nurse crop, the land is unproductive and idle for one growing season.

If the climatic conditions of any region are such as to provide favorable conditions for grass seeding in midsummer, grass seeds can be sown alone after a winter rye or winter wheat crop. By this method the land produces a crop in the season of seeding down to grass, and it is possible, if desired, to sow the grass seeds alone instead of with a nurse crop. In many parts of the North Temperate Zone alfalfa is sown in midsummer without a nurse crop in order to have an opportunity to destroy all weeds before the seeding is done and thus provide favorable conditions for the young stand of alfalfa.

In some parts of the United States, soy beans, cowpeas, Canadian field peas, and vetches are sown thickly on the land and harvested for hay or for ensilage, or perhaps pastured to live stock. When grown in this manner, they may be classed as grass crops in the planning of crop rotations, particularly so, if pastured; for, in that event, there remains a considerable portion of organic matter and manure to plow into the soil that is comparable to the turf of grass crops.

Cultivated Crops. Any crop which is so planted as to permit of inter-tillage during the crop growing season may be classed as a cultivated crop. Indian corn, sorghum, Kafir corn, potatoes, cotton, tobacco, and sugar beets are typical examples of this class of crops. Crops which permit of

inter-tillage are sometimes called "cleaning crops," because weeds may be cultivated out or cleaned from the land during the time that these crops occupy the soil. Weed seeds often become buried below the surface of the soil and fail to germinate until the plow again brings them to the surface. Then, if a cultivated crop is on the land, the weeds may be quite thoroughly cleaned out by the cultivator. Very weedy land is sometimes cleaned by growing cultivated crops two or three years in succession and plowing the land each year so that the cultivation will clean weeds from both sides of the furrow-slice.

When crops are so planted as to permit of inter-tillage, the continuous cultivation throughout the summer months

Photo by courtesy "Farmer and Breeder."

Cultivating corn with the two-row cultivator—a machine that effects economies in man labor. Cultivated crops clean the land of weeds, promote the disintegration of soil and organic matter, and prepare the land well for delicate feeding crops such as wheat.

is not only beneficial in destroying weeds, but also in pulverizing and aerating the soil, and thus aiding the processes of soil decay whereby the plant food of the soil is rendered available to the roots of plants.

It is a noticeable fact about plant growth that when the grain crops, such as wheat, barley or oats, are sown on land that was previously occupied by a cultivated crop, the yield is much greater than when grain crops are grown successively with no alternation with cultivated crops. The explanation is, that the work of inter-tillage has hastened those processes that change the raw fertility of the soil to a condition where the elements of plant food may be easily taken up by the plant. The effect of a cultivated crop on the soil is much the same as that of a bare fallow—a practice of leaving the soil bare or fallow occasionally and thoroughly tilling it during the summer months.

Catch Crops. The term "catch crops" is used to designate those crops that may be sown in the Temperate Zone to take the place of regular, staple crops that in a rotation have failed on account of unfavorable climatic conditions, or crops that may be sown with regular crops, or between the seasons for regular crops, as supplementary pasture for live stock or to produce a second marketable crop in one growing season.

The crops most widely used for this purpose are winter rye, rape, crimson clover, buckwheat, turnips, Canadian field peas, soy beans, cowpeas, and fodder corn. Examples of the use of these catch crops are as follows: Rape, soy beans, cowpeas, Canadian field peas or fodder corn may be used in a rotation to take the place of grass crops, that may have been killed by drought or a severe winter. Pasture or fodder may thus be provided instead of the regular grass meadow or pasture. Buckwheat or turnips can be sown

after the barley harvest and a crop matured before winter. Rape can be sown with grain in the spring and be used for pasture after the grain harvest. Winter rye can be sown in the autumn following the ordinary grain harvest and be used in the autumn and the succeeding spring as sheep or swine pasture, and then be plowed up in the late spring in preparing a seed bed for corn or some other late sown crop.

Photo by courtesy "Farmer and Breeder."

A "catch crop" of cowpeas sown with corn in central Iowa for annual pasture or green manure. A consistent policy of growing this crop in rotations with corn will materially increase the yields of corn.

Green Manure Crops. Green manure crops are those that are grown for the particular purpose of producing organic matter that can be plowed under and incorporated with the mineral matter of the soil. This is a practice that is commonly employed to restore worn out soils to a state of productiveness, or to improve the physical texture and fertility of sandy soils. The decaying organic matter assists in releasing and making available to plants the plant food of the soil, and also assists in maintaining a

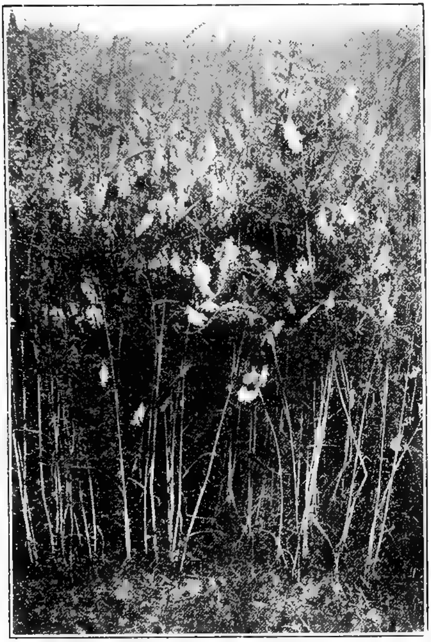


Photo by courtesy C. V. Piper, U. S. Dept. of Agriculture.

Rye and vetch for green manure or forage The rye supports the vetch plants. This is an excellent soil renovating crop for sandy soils in the North Central States, as well as other agricultural regions.

desirable percent of moisture in the soil. The most commonly used green manure crops are buckwheat, mammoth clover, red clover, crimson clover, Canadian field peas, soy beans, cowpeas, sweet clover and vetches. They grow quickly and produce large amounts of organic matter. The legume crops—crimson clover, mammoth clover, red clover, Canadian field peas, soy beans, cowpeas, sweet clover or vetches—are the best crops for green manuring, because they contain a higher percentage of nitrogenous compounds than such crops as buckwheat.

Cover Crops. The term "cover crop" is used to designate certain crops that are sown for the particular purpose of covering the land at those seasons of the year when soil is likely to be eroded and soluble plant food lost by leaching. Cover crops may also be used to prevent wind drifting of soils in the early spring, and in fruit orchards to act as a mulch that will assist somewhat in the prevention of

root killing by frost and to retard growth in the spring in order to avoid danger to fruit buds from late frosts.

Cover crops are not grown to produce marketable products but as a special means of soil protection. The crops most commonly used for this purpose are crimson clover, rape, buckwheat, winter rye, soy beans, cowpeas and the vetches. The manner in which these crops cover and protect the soil may be illustrated as follows: Crimson clover, a quick growing annual crop, is sown on a hillside field subject to erosion and to loss of soluble plant food by leaching and running water. The crop of crimson clover is sown in the autumn following a regular crop and soon the roots penetrate the surface soil and the growing plant absorbs the soluble plant food. Thus, when the succeeding winter and spring come on with their storms of wind and rain, the soil is somewhat withheld from erosion by the roots of the cover crop, and much of the soluble plant food of the soil is stored in the roots, stems and leaves of the cover crop in such a way that loss is minimized. As spring comes on and the crimson clover starts into life again, the crop with its stored supplies of plant food is plowed under in preparing the land for the succeeding marketable crop. In regions too cold for crimson clover to survive the winter, such crops as winter rye are used for the same purpose. Rape, buckwheat, soy beans and cowpeas may be used with good results, even though winter kills down the plants.

PROBLEMS AND PRACTICUMS

(1) What two botanical families comprise the majority of the Temperate Zone crops cultivated by man?

(2) What are the advantages to be gained by seeding cereal and grass crops with the grain drill instead of the broadcast seeder? Are there any disadvantages?

(3) What grain crop is the best "nurse crop" to use in your locality when seeding land to grasses, clovers or alfalfa? Compare wheat, rye, oats, barley and flax. Can grass crops be sown satisfactorily in a corn crop in your locality? If so, outline methods.

(4) Compare the advantages and disadvantages of seeding alfalfa in your locality with a nurse crop. What advantages are to be gained by sowing alfalfa without a nurse crop in midsummer?

(5) Why does the bare fallowing of land usually increase the yield of the crop following? See page 350.

(6) Why is it inadvisable to bare fallow land except to destroy noxious weeds? See pages 297 and 360.

(7) Why is it better policy to alternate grain and grass crops with a cultivated crop rather than with the bare fallow? See pages 297 and 360.

(8) How many days does it take in your locality to mature a crop of wheat, oats or barley? How many days does land commonly lie idle in your locality between small grain harvest and the close of the pasture season? Estimate the value per acre of this period of time if the land were occupied by an annual catch crop pasture completely utilized by live stock. (Get data on this question from local farmers. Make an estimate for dairy cows, fat cattle, young cattle, or sheep.)

(9) What is the best green manure crop for your locality? Why?

(10) What are the soil and climatic conditions that make it advisable to use cover crops? In what part of the United States are these conditions commonly found?

(11) Study the modern types of machinery used in planting the grain, grass and cultivated crops. Ascertain the conditions which best fit the use of the various types of grass seeding machines.

(12) How much seed should be sown per acre for the various crops noted in this chapter? See page 454.

(13) Why is it customary to sow less seed in a semi-arid climate than in a humid climate?

CHAPTER II

EFFECT OF CROPPING ON SOIL PROPERTIES

Great differences exist in the effects which the various field crops have on the physical and chemical properties of the soil, and the student of field and crop management must understand these facts before it is possible for him to realize the advantages in rotating the grain, grass and cultivated crops. In considering the field crops from this point of view, namely, the effect which their growth has on the physical texture of soils and the supply of available plant food in the soil, they may be roughly divided into seven groups as follows: 1. Humus producing crops. 2. Humus destroying crops. 3. Crops which gather atmospheric nitrogen. 4. Gross feeding crops. 5. Delicate feeding crops. 6. Deep rooted crops. 7. Shallow rooted crops.

Humus Producing Crops. The structure of all plants is chiefly composed of carbon, hydrogen, and oxygen, elements that the plant obtains from the carbon dioxide of the atmosphere and the water in the soil. These compounds, carbon dioxide and water, are abundant in nature and usually accessible to cultivated plant life. The chief portion of organic matter, therefore, is easily produced and easily accessible as a constituent of the soil.

Organic matter during its process of decay in the soil is called humus. Humus is very valuable in soils, because its presence determines, to a large extent, the moisture supply and the ease with which the soil may be tilled. Soils lacking in humus are hard and gritty, difficult to till, and incapable of allowing the passage of air and water in such

amounts as to favor crop growth. Humus acts as a sponge within the soil. In sandy soils it absorbs and holds moisture, and in clay soils it makes the soil loamier and easier to till, more porous and accessible to air, and prevents baking, cracking, and the consequent rapid evaporation of moisture.

Humus, also, during its process of decay in the soil, produces certain acid solvents that assist in putting the plant food compounds of the soil into solution, so that plant roots may absorb and make use of them. It may thus be seen that humus is a very important soil constituent, and that the productivity of the soil depends to a large extent upon the humus supply.

All crops are humus producing in their natural and wild existence; for the plant structure, when its life is completed, decays into humus and is incorporated in due time with the mineral matter of soils. Virgin soils are always rich in humus and when the breaking plow inverts the wild sod the accumulated humus supply of centuries may be seen. In the forest, likewise, the dead leaves, the twigs, and the old bark, all decay and become mixed with the mineral matter of the soil, holding moisture for the tree roots, and in their decay releasing the elements of plant food from their fixed condition in chemical compounds.

When man uses the soil to produce vast acreages of wheat, corn or cotton, he usually checks the natural production of humus and fails to supply the soil with organic matter to offset the decay and consumption of the original supply. In many of the great grain fields of North America many tons of straw are burned every year, thus wasting in smoke and gases the supplies of humus that should be returned to the soil to keep it mellow and productive. In the sorghum, soy bean and millet fields of Manchuria in North China, humus is destroyed and wasted in a still more reckless

manner; for not only are the stalks of the crops taken from the land and used for fuel, but even the roots of the crops are dug up and burned.

Such practices may continue on the most fertile soils for several generations, but eventually the day of reckoning arrives. The soil becomes hard, gritty, underlaid with a plow hardpan, and unproductive. Then the land is either abandoned to nature to have its humus supply again built up, or it is reclaimed and cropped scientifically by men who understand the production and control of humus, and who can soon restore a supply of humus to the barren soil.

A humus equilibrium can undoubtedly be maintained in the soils from which men produce their staple crops, providing the straw and roots of grain crops are either returned directly to the soil and plowed under or used as feed and bedding for live stock and returned to the soil as manure, this supply of humus being augmented occasionally by growing grass crops that produce a turf of roots and stems that increase the humus supply of the soil when plowed under. In some of the wheat growing districts on the Pacific Coast, where the grain is cut with a header and the straw plowed under, the soil is still mellow and productive after many years of continuous grain growing.

Those crops that are commonly called "humus producing crops" are the meadow and pasture crops, such as timothy, red top, blue grass, brome grass, clovers and alfalfa. The clovers and alfalfa are particularly valuable in this respect; for they produce large taproots underground and also branch profusely, so that, even though the plant above ground is cut off for hay or pasture, a large amount of organic matter remains to be plowed under and mixed with the mineral matter of the soil.

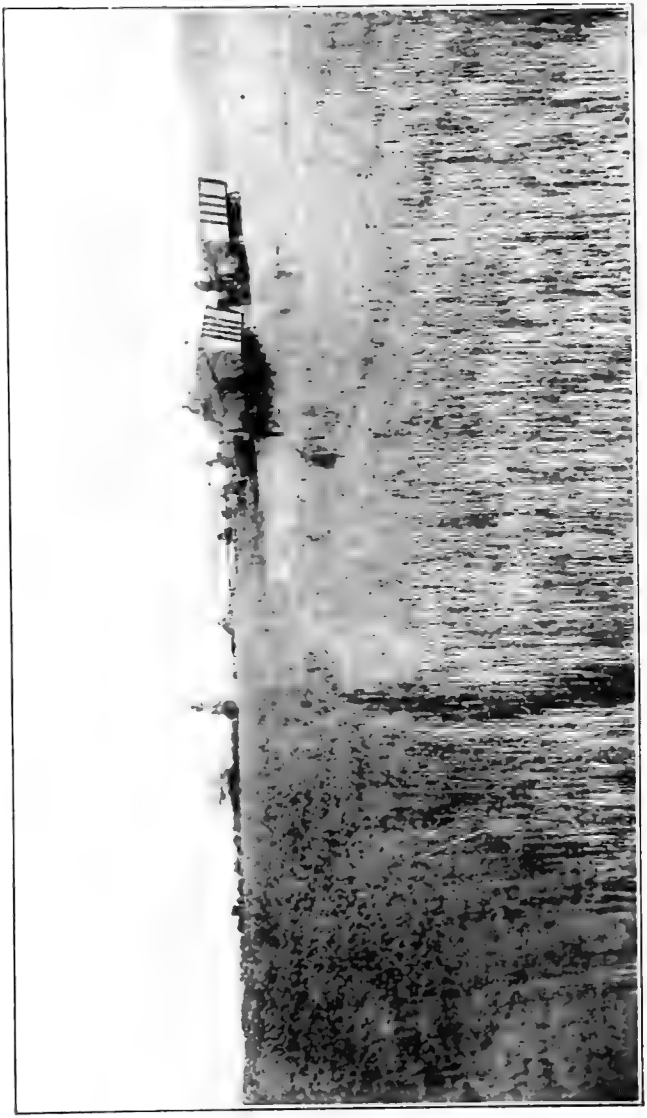


Photo by courtesy Northern Pacific Railway.

Headers cutting wheat in Washington. Plowing under the large amount of straw left by the header maintains the humus supply of the soil much better than when grain is cut with a binder and the straw piles burned

It may thus be seen that the term "humus producing crops" is applied to those crops that will produce supplies of humus for use in the upkeep of the soil, and will also, during the time they occupy the soil, produce marketable crops of hay and pasture. All crops produce humus, but, in case of the grain and cultivated crops, the greater portion of the plant is usually removed from the soil and its organic matter consumed, except where corn or grain is fed off in the field or the straw of headed grain is plowed under or where such crop products are fed to live stock and the manure returned to the land. The grasses and clovers, however, will produce humus that can be plowed into the soil, and also permit the marketing of a portion of the plant structure. Hence the term "humus producing crops" has been applied to them.

Humus Destroying Crops. Such crops as corn, sorghum, Kafir corn, wheat, rye, millet, buckwheat, barley, oats, cotton, flax, hemp, potatoes, and sugar beets, when grown for their seed, forage, root or fiber value, are often called "humus destroying" or "humus consuming crops." This term is not applied to these crops because they actually consume humus as a form of plant food and other kinds of crops do not, but only because the residue of stubble and roots from these crops, when plowed under, adds very little humus to the soil. Experience has shown that, when this class of crops is grown continuously on the same area of land, the humus equilibrium is not maintained; in other words, the rate of humus decay and consumption is faster than the rate of production.

When such crops as corn and cotton are grown as cultivated or inter-tillage crops, the decay of humus is particularly rapid. The constant stirring of soil with inter-tillage implements promotes aeration and moisture conservation, thus providing favorable conditions for the decay of organic matter. The rapid decay of organic matter in the soil,

caused by inter-tillage crops, and the attendant disintegration of mineral matter resulting from the solvent action of acids liberated from the decaying organic matter, produce a very favorable condition for the succeeding crop, because soluble and available plant food is produced in large amounts. When these inter-tillage crops, such as corn and cotton, are grown continuously on the same piece of land, the inevitable result is the destruction and consumption of humus at a faster rate than the rate of production, and thus the soil in time loses its natural loaminess, ease of tilth, and productivity.

Crops Which Gather Atmospheric Nitrogen. Nitrogen salts, one of the most important groups of plant food, are

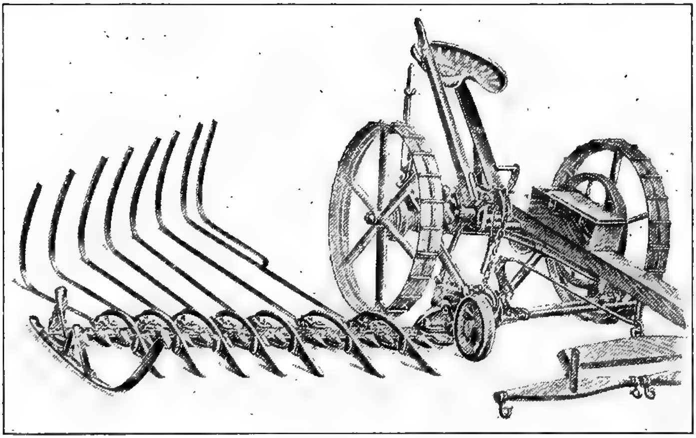


Photo by courtesy Blocki Manufacturing Company.

Pea harvesting attachments that can be put on any standard mower. The vines gather into a cylindrical roll behind the cutter-bar and are dropped out behind in a neat windrow. Clearance is given for the following round of the team and mower. The vines dry nicely in the windrow. The pea harvester is also very useful for cutting clover and alfalfa seed crops, as well as all legume forage crops.

exhausted rapidly from soils by the seed bearing grain and cultivated crops. How to keep the soil supplied with this important plant food has ever been a perplexing problem. The nitrogen of the soil compounds, when assimilated by the plant, is stored up in the seeds and tissues of plants in organic compounds. The foods containing large amounts of nitrogenous organic compounds are eagerly sought by man on account of their strength and muscle giving properties. When food products containing nitrogen are taken into the human or animal body, the nitrogen is used to repair and strengthen the body tissues. The worn out tissues of the body are voided from time to time and these waste products also contain nitrogen.

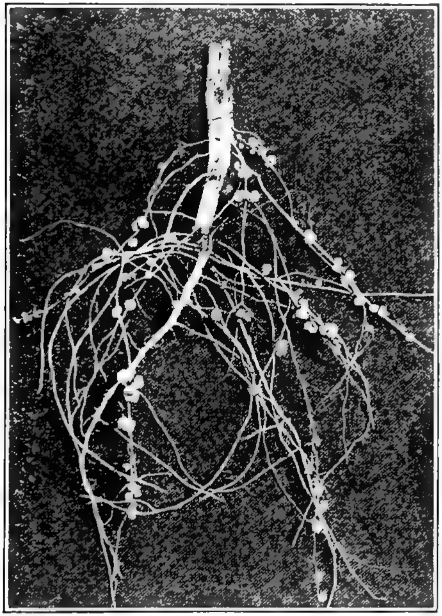
Could all the waste products from human and animal bodies be returned immediately to the soil as soon as voided, the loss of nitrogen from the soil would not be noticed, but this result is rarely accomplished. Probably not one fourth of the original amounts of nitrogen in the soil are returned again in the waste of animal bodies. This loss occurs because the waste products are only partially preserved and because fermentation, oxidation, and leaching cause great losses in those portions of animal waste that are preserved and returned to the soil.

The waste of nitrogen as well as other forms of plant food through city sewers is enormous. Countless tons of nitrogen and other essential forms of plant food are brought into the great cities in various food products which become a total loss to the agricultural soils of the nation, because, in the cities, all of the waste products containing plant food are diverted into the rivers and the ocean. It is possible and practical to recover the fertilizer materials of sewage in septic tanks where the sewage is decomposed and separated into pure water and solid matter. Our American

cities, however, have never adopted any extensive plans for recovering the fertilizer value in sewage.

Until recent times it was thought that the only means for restoring nitrogen to the soil were the waste products from animal bodies and the great deposits of nitrogen salts that exist in South America. At one time the problem was regarded as serious, because the world's deposits of nitrogen salts are very limited, and because it is very difficult to recover the total waste from human and animal bodies.

Nitrogen, however, exists as a free gas in the atmosphere that surrounds the Earth, and some years ago experiments in chemistry revealed the fact that certain species of small plants (bacteria) had the ability to assimilate atmospheric nitrogen. These bacteria live together in great colonies and attach themselves to the roots of growing plants belonging to the legume family — peas, beans, clovers, and alfalfa. These colonies of small plants are parasitic to a certain extent on the legume plants, but they in turn supply the legume plant



From Bul. 94, Illinois Agr. Expt. Station.

Cowpea roots, about one third natural size, showing the tubercles that contain the nitrogen gathering bacteria.

with nitrogen assimilated from the atmosphere. Thus the tissues of legume plants contain atmospheric nitrogen fixed in certain organic compounds, and when the roots and stubble of these crops are plowed under and buried in the soil, this nitrogen is eventually released from the organic compounds of the plant and combines with certain mineral elements in the soil, in which condition it is available to the roots of succeeding crops.

The legume crops, therefore, not only have great value in relation to soil productivity as a means of supplying humus, but also of gathering atmospheric nitrogen and incorporating it in the soil.

The bacteria that are the real agents in collecting and storing atmospheric nitrogen in the soil are associated only with the legume crops. No nitrogen gathering bacteria are associated with such crops as corn, wheat, millet, cotton, buckwheat, barley, oats, flax, hemp, tobacco, potatoes or sugar beets. These crops must have their nitrogenous food supplied to them in the nitrogen salts of the soil. They are all crops that soon deplete the nitrogen supply, if legume crops are not occasionally grown, or manure spread on the land, to check the loss.

Gross Feeding Crops. The field crops may be divided into several groups on the basis of the character of their root systems. Gross feeding crops are those that have strong, coarse, quick growing and widely reaching roots, that branch out in many directions in the soil and thus have a large soil area from which to absorb food and water for the plant. Typical crops belonging to this group are corn, sorghum and the coarser millets. It is a well known fact that these crops will thrive fairly well on soils that are not in condition to produce large crops of wheat or flax, and the principal reason lies in the extensiveness and greater assimi-

lative power of the root systems. Corn roots, for example, grow quickly, and soon produce in the soil an enormous net work of roots some of which extend five to seven feet.

Delicate Feeding Crops are those that have comparatively fine, slender roots that grow mainly in the furrow-slice, and, therefore, confine the crop to a comparatively small soil area from which to secure plant food. Typical crops belonging to this group are wheat, flax, barley and oats.

Gross Feeding Crops and Delicate Feeding Crops Compared. Gross feeding crops by reason of their strong root systems are said to be able to prepare their own plant food from the soil to a greater extent than crops with slender roots that are restricted to a more limited feeding area. While it is true that all crops, both gross and delicate feeders, respond profitably to the best of soil tillage, it is also true that gross feeding crops like corn, sorghum and millet, will produce relatively greater crops on rough, poorly tilled land than will delicate feeding crops such as wheat or flax. In other words, the delicate feeding crops to be truly profitable should receive the most favored places in the rotation, where the plant food would be in the condition of easiest assimilation. Wheat, for example, does not thrive well on freshly manured land nor on land that is not in most excellent physical condition. The plant food of the soil must be in a condition where it is quickly soluble, if wheat may be expected to produce large and profitable yields. Corn, however, will thrive on freshly manured soil, on soil that contains applications of coarse organic matter, and on soil where the plant food solution is not exceedingly strong.

There are many field crops whose root systems illustrate all gradations between a gross, coarse feeding crop such as corn, and a very delicate feeding crop such as wheat or flax.

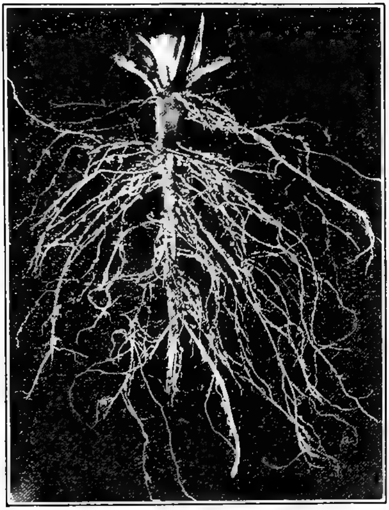
Rye, barley and oats, for example, are grosser feeding than wheat and less so than corn and sorghum. The root crops such as potatoes, beets and turnips are grosser feeding than flax and less so than corn. Clover and alfalfa, in their early periods of growth, are extremely delicate feeders and the soil must be very carefully prepared to get the crop started. If these crops are once in possession of the soil, however, their roots run deep and they become gross feeders, the roots penetrating and covering a large soil area.

Shallow and Deep-Rooted Crops. As a rule, those crops that are delicate feeders are shallow rooted, and the gross feeding crops are deep rooted. Wheat, cotton, flax, barley, oats, buckwheat, potatoes, sugar beets, hemp, soy beans, timothy, blue grass, brome grass, redtop, and cow-peas are called shallow-rooted crops, and alfalfa, clover, corn and sorghums are deep-rooted crops.

The methods by which crops are planted and cultivated determine, to a large extent, the character of the root system. Wheat, barley and oats, for example, produce a large mass of slender, fibrous roots within the furrow-slice when planted in six or seven inch rows with a grain drill. Isolated plants of wheat, barley or oats, or rows so planted as to permit of inter-tillage, would produce a deeper and more extensive root system than plants growing closely together. It may thus be seen that the natural differences in certain crop root systems are heightened and exaggerated by the methods of planting employed. Corn and wheat, for example, would produce quite similar root systems under similar methods of planting, but when wheat is sown with a grain drill in six or seven inch rows and corn is planted in hills three and one half feet apart, the root systems are very different, and wheat under such conditions is com-

paratively shallow-rooted and corn comparatively deep-rooted.

A most striking illustration of the difference between a shallow and a deep-rooted crop is shown by the root systems of wheat and alfalfa. The wheat roots are slender and fibrous and grow in greatest profusion in that portion of the upper soil known as the furrow-slice. The alfalfa roots, on the other hand, are taproots that grow straight down in the soil, penetrating to some distance in the subsoil and throwing out occasional strong lateral branches. Alfalfa roots can be easily traced to a depth of ten to fifteen feet and in some soils to an even greater depth.



An alfalfa root about one fourth to one sixth natural size. The deep taproots of alfalfa and sweet clover are powerful mechanical agents in the work of opening and mellowing subsoils.

Shallow and deep-rooted crops exert a tremendous influence on the physical texture of soils. The inevitable result of continuous cropping with shallow-rooted crops on a given area of land is to form a hard-pan just beneath the furrow slice, especially so when accompanied by shallow plowing. Such a soil cannot absorb and supply moisture properly for growing crops, and when in such condition the soil area available to plant roots is very limited. The effect of growing alfalfa or red clover, with their deep growing taproots, is to open

up the subsoil, and make it more porous and receptive to moisture, and to increase the soil area available to the roots of succeeding crops. Such crops as corn, sorghum, and Kafir corn, also have an effect on the mellowness and porosity of the subsoil, but in a less marked degree than clover and alfalfa.

PROBLEMS AND PRACTICUMS

(1) Approximately what proportion of a plant's substance is water? What proportion is dry matter? See page 295.

(2) What proportion of the dry matter of plant substance is derived from plant food in the soil? What proportion from other sources? See page 295.

(3) What is it that gives a black color to most prairie soils? Why are the prairie soils of semi-arid regions usually brown in color and the prairie soils of humid regions black in color? See reference books on soils.

(4) When grasses grow up and die down again on land for long periods of time does the fertility of the soil increase, decrease, or remain stationary?

(5) How many pounds of nitrogen, phosphorus and potassium are removed from an acre of land by a 20 bu. per acre crop of wheat including the straw? If the grain is headed and the straw plowed under what is the loss of plant food? When straw is burned what is lost to the soil other than the amounts of phosphorus, potassium and nitrogen sold away in the seeds or left in the straw ashes? See page 296.

(6) Why is it usually profitable to inoculate soil with the bacteria that are associated with the various legume crops? How may such inoculation be accomplished for alfalfa, red clover, or soy beans? See page 415.

(7) Compare the influence of the root systems of red clover, alfalfa and wheat on the physical texture of surface soil and subsoil?

(8) Examine carefully the root systems of corn, wheat, flax, potatoes, cowpeas, alfalfa and red clover while growing in the field. Use a spade and a garden hose, if possible, to study the size and extent of the root systems.

(9) Examine the roots of clover, cowpeas, soy beans or alfalfa on land well infected with bacteria and on land that has not been inoculated. Note the number and size of the root tubercles.

(10) Write a 1,000 word essay on the function of humus in soils, discussing its effects on the physical and chemical properties of various kinds of soils. Also discuss methods for maintaining or increasing the supply of humus in the soil.

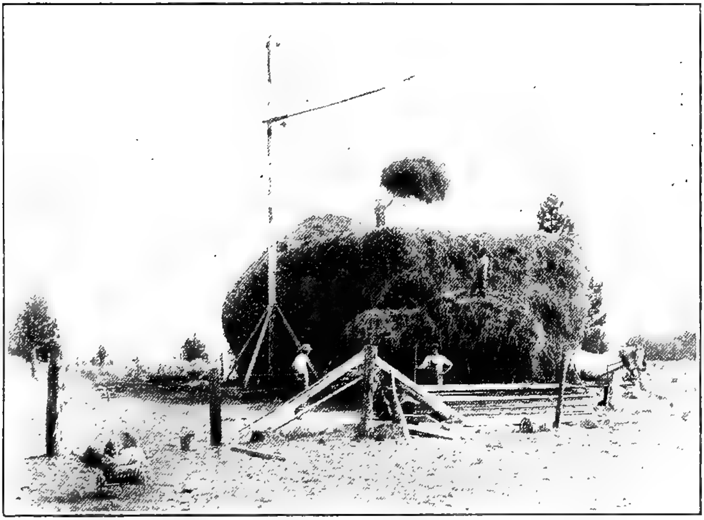


Photo by courtesy Northern Pacific Railway.

A ninety ton stack of alfalfa hay. Stacking hay with a derrick saves hard work and expense, and makes it possible to build large stacks having a minimum amount of waste hay per ton.

CHAPTER III

THE EFFECT OF CONTINUOUS CROPPING ON PRODUCTIVITY, PLANT DISEASES, INSECTS AND WEEDS

In the preceding paragraphs occasional references have been made to the effect which various classes of crops have on the physical texture and the fertility of the soil. These facts, already stated, together with other facts pertaining to this same subject, may be summarized as follows:

The Effect on the Soil of a Continuous Succession of Grain Crops. When the grain crops, such as wheat, oats, rye, barley, millet and flax, are grown year after year on the same piece of land, and the crop products removed, the supply of humus is gradually decreased until the soil loses its loaminess and its power to supply various elements of plant food in sufficient amounts for profitable yields. A soil without humus may contain abundant amounts of the necessary elements of plant food and yet be unproductive, because these elements of plant food are in firmly fixed chemical compounds unavailable to plant roots. Such a condition could not exist in a soil containing plentiful supplies of humus, for the humus provides the necessary conditions for soil decay and the placing of plant food in solution easily available to plant roots.

The grain crops also are delicate feeders and their root systems are not strong and far reaching. Plant food, especially nitrogen, must be plentifully supplied and easily accessible in the soil or else these crops do not produce heavily. The inevitable result of continuous grain cropping is to consume the available plant food of the soil at a faster

rate than new supplies are liberated, and so, ultimately, the soil is unproductive of grain crops whose roots are delicate and confined to a relatively small area. These statements are not so applicable to field peas and soy beans, when grown for seed production, as in case of such grain crops as wheat, oats and barley; for the peas and beans are crops that gather atmospheric nitrogen.

Shallow plowing has usually been a feature of continuous grain growing in the United States, and under such conditions of farming there is a tendency for subsoils to become more compact than when deeper plowing and crop rotation are practiced. A hard, compact subsoil does not make a good reservoir for the storage of soil moisture. Heavy rains are not absorbed quickly in such a subsoil and roots cannot penetrate deeply to obtain moisture. At all seasons a hard subsoil is unfavorable for root development.

Weeds accumulate very rapidly and are difficult to eradicate on land that is subjected to continuous grain cropping. Weeds rob the crops of moisture, plant food, and sunshine, and their seeds injure the market value of the cereals unless additional labor is provided to separate the weed seeds from the grain. Weeds accumulate quickly on grain growing lands, because many of them grow up with the crop and scatter their seeds on the ground before the crop is harvested. These seeds are then plowed into the soil and placed in favorable conditions to germinate and produce another generation of weeds. Weed seeds, also, may be carried over from one year to another with the seed grain, but they can be eliminated in the case of most weeds by carefully cleaning the seed grain with a fanning mill.

The Effects on the Soil of a Continuous Succession of Cultivated Crops. Such difficulties as weed eradication and the hardening of subsoils are not so apparent when cul-

tivated crops, such as corn or sorghum, are grown continuously, as under a system of continuous grain cropping. Weeds are easily kept in check by summer cultivation, and the stronger roots of these crops open the subsoil to a certain extent.

The chief trouble caused by a continuous succession of cultivated crops is that the constant stirring of the soil decays humus at a rapid rate, and, while this process is conducive to big yields during the time that the original supply of humus is great in the soil, it is a decidedly unprofitable practice when long continued. If soil is continually subjected to summer cultivation, the decay of humus becomes very rapid. During this process of decay more nitrogen may be liberated than can be immediately used by the crop or fixed and stored away in the soil as plant food. Such excess amounts of nitrogen are largely lost through leaching. Thus, in time, the soil becomes deficient in nitrogenous plant food unless it is liberally manured and fertilized.

A continuous succession of cultivated crops on hillside lands permits of annual soil erosions that soon carry away the finest and most valuable soil particles and deposit them on the low lands and river bottoms. The cultivated crop, with its loose surface soil and the furrows that lead and draw water, is an aid to the natural processes of soil erosion and should not be used continuously on hillside lands.

The Effects on the Soil of a Continuous Succession of Grass Crops. Even the grass crops, with their ability to produce humus, to prevent leaching and soil washing, and, in the case of clovers and alfalfa, to push their taproots into the subsoil, cannot be grown continuously for many years with maximum profits. When grass crops, such as timothy and brome grass, occupy the soil for many years, the upper crust

of soil becomes a thick mat of roots crowding each other for air, moisture and plant food. The crop becomes sodbound and the yields decrease greatly, due to the crowded condition of the roots. When the grass crop reaches this stage, the turf should be broken, and the plow, the harrow, and the cultivated crop be allowed to assist the decay of the turf and to loosen and improve the physical texture of the soil.

The same conditions are met when alfalfa and clover are allowed to occupy the land for many years. Red clover cannot profitably occupy the land for more than two or three years; for its natural life is only two years, and, after this period has closed, the crop can maintain itself only by natural seeding, which is always scattering and, therefore, productive of low yields. Soil is said to become "clover sick" or "alfalfa sick" when these crops remain on the land too many years. This soil condition is thought to be due to the accumulations of crop residues in the soil which prove unfavorable to the continuous growth of one kind of crops. This simply means in a practical sense, that the conditions within the soil have ceased to be favorable for the roots of these crops, and that the soil, to yield its maximum products, needs tillage and aeration and a change in the character of plant life. Old alfalfa sod can be benefited by thorough disking and manuring, and the crop is thus stimulated to further production. Even these methods, however, fail to make of alfalfa a permanently productive crop on the same soil area. Eventually a change of crop is desirable.

The Effect of Continuous Cropping on the Soil's Supply of Available Plant Food. The total supply of plant food matter in the soil and the supply which is actually available to crops are two radically different factors. Only a small portion of the total supply of the elements of plant food in the soil is in an available condition to growing crops at any given time.

The plant food of the soil must undergo certain chemical changes and must be in solution in soil water before crop roots can assimilate it. The soil must be well drained, must be supplied with decaying organic matter, and must be thoroughly tilled and aerated, if conditions are provided that will bring about the chemical changes whereby plant food is rendered available to crop roots.

If these conditions are not provided, the result is that the crops draw on the soil's supply of available plant food until it is partially or entirely exhausted and the soil becomes unproductive. The continuous cropping of any one class of crops tends to draw heavily on the available plant food of the soil and to ultimately check the chemical changes in the soil that liberate plant food and render it available for crop roots. The soil conditions necessary to the liberation of plant food are best provided when the grain, grass, and cultivated crops alternately occupy the soil.

The Effect of Crop Residues on the Growth of a Succeeding Crop of the Same Species. The unproductivity of soils subjected to continuous cropping is further explained in modern chemistry and bacteriology by a study of the effect of crop residues on the growth of a succeeding crop of the same species. It is believed that crop roots in their growth excrete waste products that remain in the soil and unfavorably affect the root growth of a succeeding crop of the same species. In time the soil may store up enough of these poisonous waste products to materially check the growth of that particular species of plants. Such a condition is avoided when various kinds of crops are alternated. The addition of animal manures to soil is also a valuable practice in remedying this unfavorable condition produced by waste products; for, in the decay and oxidation of the manure, the poisonous waste plant products are absorbed and rendered harmless,

just as the poisonous and foul matter in water is absorbed when the water is put through a charcoal filter.

It is highly probable that further investigations in soil chemistry, plant physiology and bacteriology will give many additional explanations for the unproductivity of soils subjected to continuous cropping. But, whatever the reasons and explanations offered, the remedy will undoubtedly remain unchanged, namely, the rotation of the grain, grass and cultivated crops.

Continuous Cropping and the Control of Plant Diseases and Insect Pests. The control of plant diseases and insect pests is also very difficult when continuous cropping is practiced. This is easily explained, if it is realized that the extent of an epidemic of insect pests or plant diseases is mainly dependent upon the supply of food available to the pest, and that it is the crop affected by the disease or the insect that supplies the food. Thus, if large areas of a particular crop are grown year after year in any locality, a constant supply of food is provided for these crop enemies and they thrive accordingly.

An excellent example of how a crop disease flourishes under a scheme of continuous cropping is shown in the case of "flax wilt," a fungus disease affecting the growth of the flax crop. Flax wilt is caused by a fungus that is parasitic on the roots of flax. The fungus plant develops among the root and lower stem tissues of the flax plant and gradually starves its host by absorbing the plant food in its cells. It lives in the soil for several seasons on the decaying roots and stubble of the flax crop. Thus, if flax is grown continuously on the land, the fungus disease is able to attack the successive crops of flax and cause considerable damage. If flax is rotated with other crops, however, the flax wilt fungus dies out after a few seasons, because it loses its vitality, if it cannot become parasitic on the flax crop occasionally

PROBLEMS AND PRACTICUMS

(1) What are the best methods to employ in eradicating wild oats, mustard, corn cockle, Canadian thistle, and quack grass in systems of continuous grain growing, or on a badly infested farm? See page 436.

(2) Collect samples of the important noxious weeds of your locality. Familiarize yourself with the roots, seeds, and general appearance of these weeds. Study the best methods for eradicating these weeds and discuss the effect of systematic crop rotation on the life history of each weed.

(3) Study the adjustment and operation of the fanning mill to separate various kinds of weed seed from seed grain.

(4) Examine the soil in some field that is known to have grown cultivated crops for a long term of years, also the soil in some fields where meadow and pasture crops or green manure crops have been alternated with cultivated crops. Compare these soil samples carefully in the laboratory.

(5) Examine the furrow-slice area of an old timothy sod. Note the number and extent of the roots in proportion to the amount of soil.

(6) Learn the essential facts about the life histories of the chinch bug, Hessian fly, army worm, grasshopper, flax wilt, potato scab, and corn smut, and find out what effect continuous cropping has on these crop enemies. See page 428 of this book, also reference books on entomology.

CHAPTER IV

ADVANTAGES OF CROP ROTATION

General Results Accomplished by Crop Rotation. Crop rotation has been previously defined as a system of growing the grain, grass, and cultivated crops on a given area of land in such order and such succession as to keep the soil in a high state of productivity. From the preceding paragraphs it may be noted that successions of grain crops such as wheat, barley and oats; cultivated crops, such as corn and cotton or corn and potatoes; or successions of grass crops, such as timothy followed by clover and brome grass, are not rotations or changes of crops that vary much in their effect on the productivity of the soil. They are merely successions of crops bearing different names, but having similar effects on soil productivity.

When the grain, grass, and cultivated crops, however, are alternated on the land, the result is, that, with thorough tillage methods, the soil is kept free from weeds and in a condition of good tilth and productivity. The rotation of grain, grass, and cultivated crops provides a system of field management in which the humus consuming and humus producing crops, nitrogen consuming and nitrogen gathering crops, and the deep and shallow rooted crops alternately occupy the soil. As a result, the furrow-slice and the subsoil just beneath the furrow-slice are kept in a continual state of decay, so that plant food is at all times available to plant roots and crop residues are not injurious to succeeding crops.

Crop Rotation and the Control of Weeds, Crop Diseases and Insect Pests. Noxious weeds have great difficulty in maintaining their existence on land subjected to a systematic

rotation of grain, grass and cultivated crops. If weed seeds accumulate during the time that grain crops occupy the land, the weed plants in succeeding years must contend with strong growing grass crops for the possession of the soil or be uprooted by cultivation during the period when cultivated crops are on the land. Many weed seeds, buried in the soil, lose their vitality during the years that grass crops occupy the land. If the weed seed possesses the power of remaining dormant yet vital for several years, it will not be destroyed by the grass crop, but will come to light and flourish as soon as the grass land is plowed up. Its chances for propagation, however, are very slight if a cultivated crop is grown, for the process of inter-tillage during the summer months is pretty sure to destroy the growth of weeds.

The rotation of various kinds of crops on the land is undoubtedly a severe check to widespread epidemics of such fungus diseases as rust, smut and flax wilt or insect pests such as chinch bugs, Hessian fly, army worm, and grasshoppers. The reasons are that in case of crop rotation the extent of the area of any given crop in any region or locality is limited, as compared to vast areas of the same crop contiguous to one another. Thus the epidemic cannot accumulate so rapidly and spread so far, with attendant losses, because the area of the crop on which the epidemic feeds and accumulates is interspersed with areas of other crops. Likewise it is more difficult for crop diseases and insect pests to carry over from one year to the next, if various classes of crops are being alternately grown on the soil; for a sudden change in the methods of soil preparation and kind of crop that occupies the soil will disturb and interrupt the propagation of the fungus disease or the insect pest.

Crop Rotation, The Use of Live Stock, and the Relation Which Live Stock Has to Soil Fertility. A succession of

crops that does not include hay and pasture crops is sure to be destructive to the humus supply of the soil. Green manure crops, it is true, can be occasionally introduced and the organic matter which they produce plowed under to enrich the soil. But the green manure crop is comparatively expensive. It entails an outlay for seed and labor, and it gives no direct returns—only a return in the increased yield from succeeding crops. The so-called grass crops, however, will provide humus supplies for the soil and also yield marketable products in the form of hay and pasture crops.

To obtain the greatest possible returns from these grass crops it is necessary that live stock be kept on the farms. Without live stock to utilize hay and pasture crops and to

Photo by courtesy "The Farmer."

Mowing the "grass crop" of clover and timothy. Rotation meadow and pasture crops, utilized by live stock, offer the easiest and cheapest method for maintaining the soil's supply of humus.

manufacture meat and milk therefrom, the grass crop, in many localities, has no market value, and can be regarded as a profitable part of the rotation only in the same sense as a green manure crop is regarded profitable, namely, as a producer of humus. In some localities hay products have a cash value, and the grass crop portion of the rotation can be turned into cash without the use of live stock on the farm. When these methods are followed, however, there is a loss of humus and plant food from the soil that would largely be recovered in manure, if the grass crops were fed to live stock.

Agricultural experience, the world over, has shown that in the long run the system of farming that includes live stock and grass crops is the most profitable. When good markets exist for live stock products, the grass crop portion of the rotation is usually more profitable than the grain or cereal portion, providing, of course, that the grass crops are intelligently grown and that good types of live stock are used and intelligently managed. Grass crops are more cheaply produced than grain or cultivated crops (average cost about one half that of the other crops) and the cost of a pasture crop is very little besides the fixed charges on the land, as the live stock harvests the crop free of costs. The marketing charges for live stock products, per acre of land, are much less than for grain products, because the crop products fed to live stock are concentrated by the animals and delivered in the markets in the least bulky form.

Live stock farming as a business is much more difficult to manage than grain farming. It requires more diversified knowledge and more capital. It is, therefore, rarely undertaken by the pioneer farmer on virgin soil areas adapted to grain growing or associated with grain production in an intensive scheme of farming in regions of sparse population not tributary to great centers of dense population. But, as

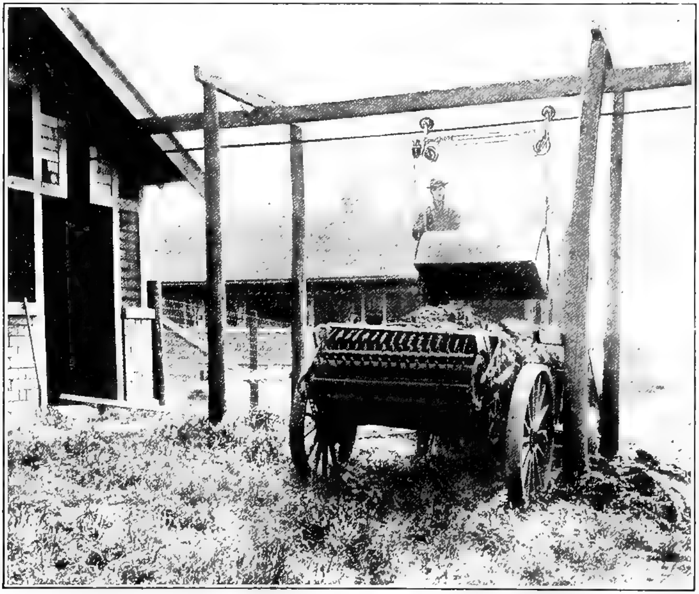
agricultural regions become thickly settled and the soil loses its natural stores of humus and available fertility, successful agriculture becomes almost dependent upon the use of live stock.

It is not difficult to see why live stock is so essential to a permanent and abiding system of agriculture, if thought is given to the differing effects which continuous grain cropping and live stock farming have on the productivity of the soil. In case of grain farming, the mineral elements of the soil that have been taken up by the crop are sold away entirely from the farm; the humus, nitrogen, and other plant food supplies of the soil are reduced too low for successful crop growth; and the shallow rooted crops soon put the soil in an undesirable physical condition. When live stock farming and grain farming are combined, however, the soil tends to stay permanently in a productive condition. Grass crops accompany the use of live stock, and the taproots of clover and alfalfa open and mellow the subsoil, while the matted turf of roots and stems produced by meadow and pasture crops, when plowed under, adds humus to the soil, and maintains a desirable physical condition within the soil. Morever, only small amounts of plant food are sold from the land when live stock farming is combined with grain culture. The manure and urine from live stock contain more than three fourths of the original elements of plant food taken up by the plants and consumed by the live stock. Thus, if these waste animal products are returned to the soil soon after they are voided, the actual loss of plant food is greatly lessened.

Experiments in crop growing have always shown that, no matter how skilfully crops are grown and rotated, the total yield of crop products through a series of years from unmanured fields is never equal to the yield from a similar rotation in which the land is occasionally manured. The beneficial effects of manuring soil can be noted for many

years after the manure has been applied. Not only does manure directly add available plant food to the soil, but it also provides humus and acid solvents that assist soil decay and make supplies of raw plant food available to crop roots in succeeding years.

The most desirable system of cropping, therefore, as regards soil fertility, is one in which the grain, grass, and cultivated crops are alternated, and in which the grass crops and a portion of the grain crops are fed to live stock, the manure from the live stock being returned to the soil as soon as possible after it is voided.



The litter carrier takes the manure from the stalls to the manure spreader at the minimum of expense. During late autumn, winter and early spring manure should be hauled directly to the fields to avoid losses in value from leaching and fermentation.

The problem of maintaining soil productivity without live stock is more difficult than with live stock. Without live stock and grass crops, the farmer must resort to commercial fertilizers (the by-products of meat packing plants or the nitrogen, phosphate, and potash salts taken from mines) and green manures, if the soil is kept in a continual state of high productivity. Both of these processes demand an advance outlay of money and labor, and the returns are not direct, as in the case of live stock. Green manure crops, however, are of great value in keeping soils in good tilth and they afford a good substitute for grass crops and

When fall plowing is leveled with the harrow, it is not difficult to spread the manure on the plowing during the winter months. Spring disking works the manure into the seed bed where the plant food is available to young crop roots, and where the manure mulches the land during the summer season. This is the ideal method for preparing corn ground.

the manure from live stock. They may be grown as catch crops between regular crops and plowed into the soil when they have matured sufficiently to have developed a large mass of foliage, and thus they will not seriously interfere with the growing of regular market crops.

The addition of large amounts of organic matter—produced by a green manure crop—to a worn out soil increases the productivity of the soil very noticeably, and, in agricultural regions where great live stock markets do not exist, where grass crops cannot be universally grown and profitably fed to live stock, or where the natural preference of the farmer is for extensive grain, corn or cotton growing, the occasional use of green manure crops is a practical necessity in maintaining soil productivity.

Crop Rotation and the Maintenance of The Soil's Supply of Nitrogen, Phosphorus, and Potassium. Among all the chemical compounds of the soil that are assimilated by crops during their growth, those compounds containing nitrogen, phosphorus, and potassium are most essential to the development of the plant. In previous paragraphs it has been shown that nitrogen can be supplied to the soil by means of legume crops and the nitrogen gathering bacteria associated with them. Thus it is possible to restore and even increase the supplies of nitrogen in the soil. The soil's supply of phosphorus and potassium, however, is dependent upon the original supplies in the rock materials that make up the body of the soil. The total amounts of these elements of plant food in the soil can be increased only by the addition of commercial fertilizers which contain phosphorus and potassium, such as ground bones, phosphate rock, wood ashes, and the Stassfurt potash salts from Germany. These fertilizers are expensive and impractical of use for a vast majority of the world's farmers. Thus it may be seen that

the original supplies of phosphorus and potassium in the soil must always be the main supplies for plant growth. Potassium is more abundant in soils than phosphorus. Phosphorus is more likely to be lacking in soils than any other element of plant food.

Only a small portion of the phosphorus and potassium compounds of the soil is in such a form that plant roots may assimilate it. The larger part is quite firmly fixed in nearly stable chemical compounds, and the disintegration of these compounds and the releasing of the supplies of phosphorus and potassium is a slow and gradual process. Gradual disintegration of these chemical compounds is absolutely necessary, if the soil continues to be productive. The necessary conditions in the soil to bring about this disintegration are: (1) the presence of decaying organic matter and the acid solvents produced therefrom; (2) the presence of moisture in sufficient amounts for plant growth; (3) a condition of soil tilth that facilitates the movement of air in the soil; (4) the presence of certain soil bacteria which assist in the decay of organic matter and the production of acid solvents, such as nitric acid.

When these conditions are maintained in the soil, the decay and disintegration of soil material are continuous, and all naturally productive soils will continue for long periods of time to yield phosphorus and potassium in sufficient amounts for good crop growth. If the method of farming fails to provide these conditions, however, a severe check is given to the production of available phosphorus and potassium, and crops are soon starved for these necessary plant foods.

When true crop rotation is practiced, with live stock to utilize pasture and forage crops, the farmer needs to worry but little over the supplies of phosphorus and potassium for his crops, providing the soil is not naturally deficient in

these elements of plant food. Humus producing crops keep the soil well supplied with humus and acid solvents. Animal manures provide humus and acid solvents as well as return to the soil actual plant food which crops have taken up in their growth. The cultivation and tillage of the soil necessary for the grain and cultivated crops aerate the soil and keep it in good physical condition. Under these conditions, as soil ages it keeps in a productive condition and its supplies of plant food are renewed from within.

As time passes, the plow and the cultivator run a little deeper, year by year, and fresh soil is brought into the furrow-slice where its stores of phosphorus and potassium are liberated for the crops. Soils that are naturally deficient in phosphorus, or soils that have been badly worn by crops which remove large amounts of phosphorus, cannot be kept productive, so far as phosphorus is concerned, through crop rotation and careful tillage. Under such conditions there is no large reserve supply of phosphorus to draw on and phosphate fertilizers must be used to amend the phosphorus deficiencies of the soil and to thus maintain crop yields at a high level.

It is a mis-statement of fact to say that crop rotation increases the fertility of the soil, for this it does not do. As a matter of fact, crop rotation causes greater amounts of plant food to be taken from the soil than the practice of continuous cropping, because crop yields are usually larger. The advantages lie in the fact that plant food, under a crop rotation system, is drawn from a more extensive soil area than under continuous cropping, and that a physical condition is maintained in the soil that continually makes new supplies of plant food available to the crops from the reserve supplies in the soil. In the one case soils may become barren and unproductive, because the plant

food of the soil is not in an available condition, and in the other case productivity is maintained for long periods of time, because the reserve plant food of the soil is made available to crop roots. Furthermore, when crop rotation is accompanied by animal husbandry the actual loss of plant food from the soil is much less than it would be otherwise; for live stock provides a check to the direct outgo of plant food.

Crop Rotation, Farm Labor and Business Management. The advantages previously accredited to crop rotation have referred mainly to the problems of soil fertility and productivity. Successful agriculture in modern times, however, is by no means confined to the art of preserving soil fertility. Business and commercial principles are as important factors in farm management as the scientific principles of soil management or the principles of animal husbandry.

As the agriculture of any nation emerges from the barter stage and enters the realm of commerce it becomes essential that the farmer, if he be successful, shall be something more than a tiller of the soil. Agriculture in modern times is becoming complicated. The farmer comes in contact with the commercial problems of the markets and the problems of farm labor in a much more intimate manner than in the days when each community satisfied its wants with the local products from the soil and the forest. Not only does the march of civilization impose on the farmer the task of mastering knowledge about soil fertility, but also the task of mastering system and business methods in the conduct of his affairs. The farming methods that existed in the pioneer days of a nation become obsolete as the land becomes fully occupied and of high value, and as the people extend their business from petty local trade to foreign commerce.*

*See discussion at end of chapter on "Value of Land a Factor in Determining the Most Profitable System of Farming."

Systematic rotation of crops is a great aid to the successful management of any farm. It is not the one and only remedy for worn out soils and for badly managed farms, but it is one of the fundamental principles to observe in giving business system and science to the management of a farm. The farmer who has planned a scheme of crop rotation suited to his conditions, and put that scheme into operation, has built

Photo by courtesy Deere and Company.

The side delivery rake windrowing clover and timothy hay. The hay is dried on one side in the swath and then rolled into loose windrows to complete the drying. When the hay is handled from the windrow with the hay loader, labor is economized and there is but small loss of leaves.

his business on a sure foundation, and the farm can be managed much more systematically and efficiently than without a definite, basic plan of crop production.

Many advantages of an economic or business nature can be cited as the result of systematic crop rotation. In a general sense, crop rotation distributes and diffuses farm labor through the various seasons of the year and minimizes

the acute demand for labor at the planting and harvest seasons; and this is a most important feature of farm management. The farmer whose business is confined to growing one or two of the staple crops such as wheat, corn, cotton, or potatoes, must keep horses, machinery, buildings and labor available to plant and harvest these crops in the proper seasons. If he is compelled to hire day labor during these seasons of seedtime and harvest, he must compete in the labor market with thousands of other farmers seeking labor at these seasons, and must pay high wages for his extra help. During the winter and some of the summer months, horses, machinery and men must be idle on these "one crop" farms, and thus the fixed charges for upkeep of horses, machinery, and other forms of fixed capital, are comparatively high, because the most efficient use possible is not made of this portion of the farmer's capital.

Contrast this one problem of labor on the "one crop" farm with the situation on a farm where crop rotation is practiced. It is self-evident that, when a variety of crops such as wheat, barley, corn, potatoes, and the meadow and pasture crops are grown on the same farm, the labor of planting, harvesting and preparing the soil for crops will be distributed through longer seasons than if one or two crops only were grown on account of the difference in the crops themselves, and thus the problem of keeping horses, men and machinery constantly employed is at least partially solved.

Crop rotation, with its inclusion of the meadow and pasture crops, also demands that live stock be kept on the farm to make profitable use of these grass crops. The keeping of live stock also distributes farm labor through the various seasons and provides profitable winter work for men and horses when the "one crop" farmer and his horses are idle and unproductive. Some winter work can always be found

when live stock is one of the farm's enterprises. The work of hauling and distributing manure, grinding feed, and the care of the live stock keeps the farmer, his men, and his horses busy at all times. Of course arguments like these do not appeal to men who have no desire to work steadily and make the most of their capital and their labor, but they are

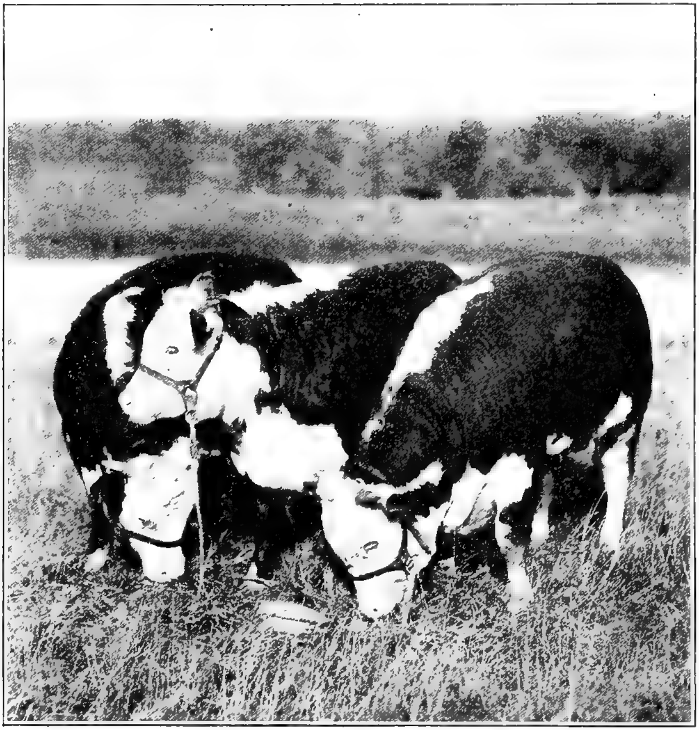


Photo by courtesy "The Farmer."

With good calves, good milking mothers, clover or alfalfa pastures, rich grain rations, and some succulent feed such as ensilage or roots, baby beef can be marketed at fifteen or sixteen months of age at a profit that greatly enhances the value of the crops utilized.

logical arguments to the farmer desirous of systematizing the business side of agriculture. These arguments become particularly important in regions where land values are high and where transient labor is scarce and costly.

When forage crops, as well as many kinds of grain crops, are fed to live stock, it is possible to enhance the value of crops. Live stock feeding is, in reality, a manufacturing enterprise, the products of which have a value greater than the raw products out of which they are made. When forage crops and grain are intelligently fed to good types of live stock, the value of the crops is usually increased to a considerable extent. This feature of animal husbandry is distinct from the problems of soil productivity, and is worthy of consideration as an important business feature of farm management. The finished product usually sells for a greater profit than the raw product. The farm manager who is a good husbandman can usually obtain a higher price for many of his crops when marketed through live stock than when crops are directly marketed.

The relation of crop rotation and live stock to the waste products of farming is a matter of considerable importance in farm management. It is always a noticeable fact about "one crop" farms that waste occurs, because the handling of one large crop in a short period of time forces hastily performed work that is often so careless as to cause waste and damage, particularly at the harvest season. Large values are lost in waste crop products also, on all farms where live stock is not kept. For example, in the harvesting of potatoes, many bushels of small potatoes are always left on the fields by the pickers, as well as the bruised and covered tubers left by the diggers. If swine or sheep can be driven over the potato fields after the marketable crop has been removed, they will literally grow fat on the waste part of the harvest. When

Canadian field or wrinkled peas are harvested, it is impossible to so harvest the crop as not to leave several bushels per acre of waste peas on the land. Swine or sheep will fatten at no expense on these waste products. When corn is husked in the field, also, there is always some waste that cattle and hogs will utilize, if the farm manager has the live stock available at the proper time. It is an old saying that "sheep will live on the waste products of the farm," and it is true. The farm manager cannot neglect the waste products of crop growing, if he plans to make the greatest returns possible from his land and his equipment. Crop rotation and the use of live stock reduce the losses on crop waste products to the minimum.

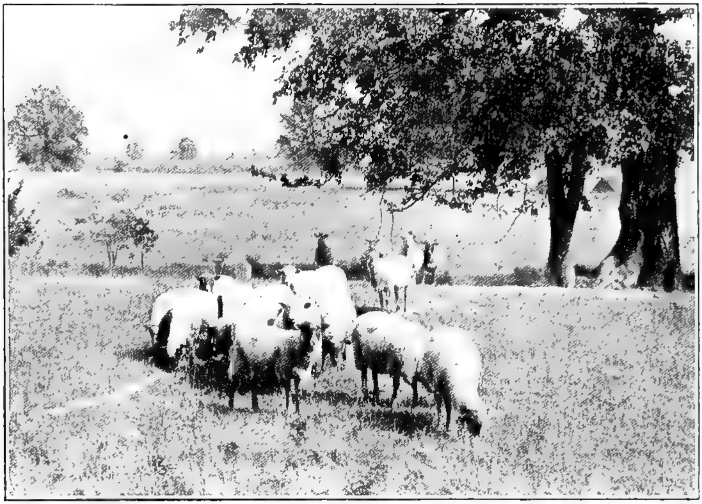


Photo by courtesy "The Farmer."

A small band of sheep is a profitable investment on any farm. They help the farmer to keep weeds under control, and they pay dividends from much of the waste material incidental to crop production.

Crop rotation is sometimes said to provide insurance against loss from fluctuating markets and from climatic crop risks. There is some truth in the saying. Sudden and violent market fluctuations in various farm products often mean great gain or great loss to the producer. If "one crop" farming is practiced, the farmer may occasionally have a large stock of produce on hand to sell in a high priced market and thus reap great profits; but years of low prices may affect his profits adversely in the same proportion. Farmers who practice crop rotation, however, must market a variety of products each year, and low prices in one class of products may be counterbalanced by high prices in another class of products. The rotation plan is more reliable and less subject to the ups and downs of business than a scheme of farm management built on one or two crops.

The same arguments apply to the losses that occur from unforeseen and unfavorable climatic conditions. Storms or drouth that severely injure wheat may not affect corn, and a season of very heavy rain that may injure corn will increase the products from meadows and pastures. When all these crops are being produced annually, the danger from loss due to drouth, heavy storms, or excessive rain, is greatly minimized, and the system can be said "to provide insurance against loss from climatic conditions."

The fact that live stock is usually kept on farms where crop rotation is practiced is an important factor in minimizing losses from unfavorable climatic conditions. For example, if a crop of small grain is badly lodged after it is headed out it is almost a total loss unless it can be pastured off at once. Again, in seasons of drouth, the straw of small grains may be too short to permit of cutting with a binder, and unless live stock is available to pasture off such crops, the labor of plowing and seeding, as well as the seed value,

is a loss to the farm. Of course, when these unforeseen crop conditions arise, it is possible for the farm manager to buy feeder stock or to lease the land to stock owners, but in such cases the owner of the damaged crop is forced to take the short end of the bargain unless he owns his own live stock and can pasture off the damaged crop at once.

Perhaps the greatest business advantage that may be attributed to crop rotation is that it teaches system and organization to the farm manager. Crop rotation, to be successful, must be systematic and be carried out carefully and precisely. System and organization soon become apparent in all departments of a farm where regular crop rotation is practiced; for it cannot be practiced in a haphazard, unsystematic manner. It injects system and organization into all the affairs of the farm, and these things are in well nigh universal need.

VALUE OF LAND A FACTOR IN DETERMINING THE MOST PROFITABLE SYSTEM OF FARMING.

(From Bulletin 73, Bureau of Statistics, U. S. Dept. of Agriculture.)

Profits constitute one of the factors which operate to fix the market value of land. A clear illustration of the manner in which profits affect the market value of agricultural land is seen in the effect which the location of a beet-sugar factory has upon land values in its immediate vicinity. A demonstration that greater net profits can be made from sugar-beet culture than from grain growing or corn and hog farming will tend to appreciate the value of all land within the territory of the factory. Land owners will quote their land higher than prior to the establishment of the new industry, whether they are producing beets or not.

Location is undoubtedly an important factor in determining profits and, therefore, in determining the market value of land; fertility or productivity of the soil is relatively a less important factor as compared with location. Poor land near good markets and with good transpor-

tation facilities may yield greater profits per acre from crops adapted to such locations than will the most fertile soils remote from good markets. Thus good roads, the increase of city industries, the use of refrigerator cars, and many other factors of a similar nature all tend to make land more accessible, to better its location, to increase the opportunities for profit making, and to cause an increase in the market values of the land.

A number of special causes which have influenced profits in American agriculture and caused appreciation in land values are worthy of mention. The coming of the settler into the grazing lands west of the Missouri River increased the value of Dakota farm lands, because the profits per acre in wheat culture, even with poor tillage, were greater than those in grazing cattle, and as wheat supplanted grazing the price of wild land was quoted on the basis of profits in wheat, not cattle. Again, the introduction of new crops and machinery has had much to do with increasing land values. Durum wheat has made profitable much semi-arid land that was capitalized very low prior to the introduction of that crop, and many a new farm machine, the creation of American genius, has increased the profits from the soil. The partial passing of the widespread cotton-crop "lien system" in the South has greatly influenced the profits from southern soil and caused a noticeable increase in farm-land values.

It is not uncommon in modern American agriculture to find communities in which land values have doubled or trebled since the days of settlement, and yet there has been little or no change therein in the system of farming. New and improved machinery has taken the place of old and relatively inefficient machinery, and buildings have usually increased in number, size, and usefulness. The crops, the methods of cropping and of marketing have nevertheless remained unchanged in many instances, although the land has appreciated in value 100 per cent or more. In such communities the market value of the land has been influenced, not by profits on land within the territory, but by those on other land equally well located, under similar climatic conditions, that has yielded profits proportionate to the higher capitalization.

One reason why profits from farm lands are not always in proportion to the market value of the land is that men who secured homesteads or cheap land soon became independent, debts were wiped out, a living was assured, and the habit of cropping the land with the methods of early times persisted even though other men on similar land might be reaping greater profits. Such men or such communities not having

interest accounts to pay on the new valuations may not have been forced into more profitable systems of farming. Many such communities could be cited in the old wheat-growing regions of Minnesota and the corn-growing sections of Illinois. Such land may yield a fair profit on the original capitalization and enable the owner to create a surplus, but how different the situation becomes to the man who buys a piece of high priced land, places a mortgage on it at current interest rates, and starts out to make a living, to pay interest charges on the high valuation, and, in addition, to pay off the mortgage.

Land rental, or interest on the investment in land, is not usually considered an item of expense in the production of farm products, but such a charge is fully justified. If capital can be withdrawn from agriculture and yield 6 per cent in other industries, then the business of farming must be debited with interest on the investment, as well as the wages paid to labor, in the determination of net profit. On high priced land interest becomes an important item of expense as compared with conditions of relatively low land values. It is not beyond the range of possibility in new wheat regions for two good wheat crops to pay costs of production and pay for the land, but, even with equal fertility, on relatively high-priced land the situation is materially changed because the costs of production are much higher. The cost of producing wheat in S. E. Minn. is $9.86 per acre; in S. W. Minn., $8.38, and in N. W. Minn., $6.97, the chief difference in cost being accounted for by differences in land rental or in the interest on the investment. Reference should be made to the Table given herewith in which it may be seen that the cost of producing wheat is 66.9 per cent higher on land valued at $100 than on land valued at $20. Increases in the cost of producing field crops, due to changes in land value, fall heaviest on those crops that require only a relatively small application of capital and labor in their production. The increase of cost is greater for crops like wheat and clover that require but a small amount of capital and labor in their production than for crops like potatoes, mangels, or ensilage which require a relatively large amount. For example, it may be seen in this table that the cost of producing wheat on $20 land is $7.18 and on $100 land $11.98, an increase of $4.80, or 66.9 per cent. The cost of producing potatoes on $20 land is $24.56 and on $100 land $29.36, an increase of $4.80 or 19.5 per cent. The cost of producing corn ensilage on $20 land is $17.59 and on $100 land $22.39, an increase of $4.80, or 27.3 per cent.

Relation of Cost of Producing Field Crops to Land Values.

Crop.	Average cost of production per acre, exclusive of land rental.	Cost of production, including land rental, on land having a value per acre of								
		$20.	$30.	$40.	$50.	$60.	$70.	$80.	$90.	$100.
Barley—fall plowed	$5.563	$6.763	$7.363	$7.963	$8.563	$9.163	$9.763	$10.363	$10.963	$11.563
Corn—ears husked from standing stalks	7.238	8.438	9.038	9.638	10.238	10.838	11.438	12.038	12.638	13.238
Corn—grown thickly and siloed	16.392	17.592	18.192	18.792	19.392	19.992	20.592	21.192	21.792	22.392
Flaxseed—thrashed from windrow	5.314	6.514	7.114	7.714	8.314	8.914	9.514	10.114	10.714	11.314
Fodder corn—cut and shocked in field	6.912	8.112	8.712	9.312	9.912	10.512	11.112	11.712	12.312	12.912
Hay—timothy and clover (one cutting)	2.577	3.777	4.377	4.977	5.577	6.177	6.777	7.377	7.977	8.577
Mangels	29.182	30.382	30.982	31.582	32.182	32.782	33.382	33.882	34.582	35.182
Oats—fall plowed	5.869	7.069	7.669	8.269	8.869	9.469	10.069	10.669	11.269	11.869
Potatoes	23.366	24.566	25.566	25.766	26.366	26.966	27.566	28.166	28.766	29.366
Wheat—fall plowed	5.980	7.180	7.780	8.380	8.980	9.580	10.180	10.780	11.380	11.980

Note.—The average cost of production exclusive of land rental which forms the basis of this table has been computed from the total cost (exclusive of land rental) for each crop in all regions of Minnesota where statistics have been collected during the years 1902-1907. This sum of all costs divided by the total acreage in crop gives the average. The cost of production in the other columns of this table varies according to the amount of land rental or interest on investment in land—a factor of cost which varies with the value of the land. Land rental as an item of cost amounts to $1.20 (6 per cent on $20) on the $20 land and $6 (6 per cent on $100) on the land valued at $100 per acre.

The premises concerning the causes of increase in land value and the effect of "interest on investment" in the cost of production have a practical application in the study of farm management. Systems of crop rotation and farm organization must be chosen and efficiently followed which will yield an income larger than the cost. When land rental or interest on investment is considered as an item of expense, other items of cost remaining the same, the net product per acre must also increase, to yield equal rates of profit. That many localities exist in which "net proceeds" and land values are not proportionate must be conceded by all students of agriculture. The chief reason for this situation, wheresoever found, is that the system of farming and the crops grown by that system are not adapted to the economic environment of the farm. Such conditions are nearly impossible in industries other than agriculture, but the independent farmer has his living and his home whether he manages his land to secure the highest possible profits or not, and so systems of farming which, because of changed economic conditions, are antiquated persist for many years in spite of the progress which appreciates the value of land.

To illustrate the fact that certain crops and systems of farming are adapted to profitable management only under certain economic conditions, some conclusions may be drawn from the preceding Table relative to the cost of producing wheat, corn, and potatoes. Fifteen bushels of wheat per acre on $20 land at an average farm price of 66 cents per bushel will return a net profit of 13.6 per cent on the investment (i.e., on the value of the land), "net profit" being over and above the "land rental," which is counted as an item in the cost. The same crop on $50 land gives a net profit of 1.84 per cent, and on $100 land a net loss of 2 per cent. In order to secure equal rates of profit from the $50 land and the $100 land with this crop, price being the same, a yield of 23.9 bushels is necessary on the $50 land and 38.8 bushels on the $100 land. It may thus be seen that wheat is not adapted to profitable culture on high priced land—in fact, it is absolutely impossible to grow it and secure the same rate of profit as can be secured on the cheaper lands, less favorably located, but equal to or excelling the high-priced land in productiveness for wheat. Average spring wheat yields of 24 or 39 bushels can not be secured, and wheat grown on $50 to $100 land can not compete with wheat on $20 land.

Corn responds better to costly tillage, thrives better on old soils, and in regions favorable to its growth has greater possibilities for returning

a fair profit on high-priced land than wheat. Fifty bushels of corn per acre on $50 land at an average farm price of 32 cents per bushel will give a net profit of 11.52 per cent. The same crop on $100 land gives a net profit of 2.76 per cent, and on $150 land a net loss of 0.15 per cent. In order to secure equal rates of profit from the $100 land and the $150 land with the corn crop (price being the same) a yield of 77.47 bushels is necessary on the $100 land and 104.7 bushels on the $150 land. These figures indicate that the corn crop has greater possibilities for profit making on land valued above $50 per acre than wheat. Yields of 75 to 100 bushels of corn per acre are not impossible in Southern Minnesota, with good management; this will pay cost of production and give a reasonable profit on the high-priced land. The value of the corn crop can also be enhanced by feeding to cattle and hogs, and profits thus increased; and as the manure produced will tend to maintain the yields of corn at a high level this increased profit will also thus again be enhanced. Wheat can not be fed profitably under ordinary conditions except at prices below 50 cents per bushel. One hundred bushels of corn per acre is a very high yield for our average farm lands, even in Iowa and Illinois. Thus at present prices this crop under the system of farming associated with it ceases to be profitable when land values approximate $150 per acre.

Potatoes illustrate a third type of staple crop that has greater possibilities through intensive culture on high-priced land than corn or wheat. One hundred bushels of potatoes per acre at 39 cents on the farm will give a net profit of 25.3 per cent on $50 land. The same crop on $100 land gives a net profit of 9.6 per cent, on $150 land a net profit of 4.4 per cent, and on $200 land a net profit of 1.8 per cent. To secure the same rate of profit as was obtained on the $100 land with a 100 bushel crop (9.6 per cent) the yield per acre must be 119.9 bushels on land valued at $150 and 139.9 bushels on the $200 land. Such yields are possible with fair cultivation. The potato crop, then, is adapted to intensive culture on high-priced land, and large applications of capital and labor are justified by the additional returns—a condition that is not true with the wheat and small grain crops.

As land values increase beyond $200 to $300 per acre the potato crop becomes relatively unprofitable as compared with the onion crop and other garden crops requiring large amounts of labor per acre in their production. Onions, for example, under good cultivation, will yield 600 to 1000 bushels per acre, giving a gross income ranging from $200 to

$400 per acre. Strawberries, small fruits, and orchard crops are also illustrative of crops adapted to soils so located as to have a value of $400 per acre or higher. The value of land is thus seen to be a most important factor which governs the determination of the most profitable system of agriculture. The crops and the systems of farming must be in accord with land values, or financial loss is the result. Wheat, because of its low acre cost of production and its ease of storage and transportation, is adapted to culture only on relatively low-priced lands. The cost of producing this crop mounts up so rapidly on high-priced land as to make profits impossible; for the crop does not lend itself to intensive culture, and a high application of labor and capital in production can not be recovered in increased yields. When wheat is grown on land valued at $100 per acre the net product must be approximately five times as great as on land valued at $20 per acre in order to yield the same rate of profit and it is impossible to raise the yield to that point. Waste and loss are, therefore, the results of growing wheat on high-priced land, for 5 acres of $20 land will produce a much greater net product of wheat than 1 acre of $100 land. Similar illustrations might be given with other crops, such as corn, potatoes, and onions, but enough has been given to show that the most successful farm managenent demands that a system of cropping and field management be followed which is in accord with the land values. When land values are relatively low, a system of farming which raises crops capable of extensive cultivation at low cost of production per acre is usually more profitable than one producing crops of a high cost of production, and when land values are high the intensively cultivated crops are the most profitable.

Wheat farming must, of course, give some consideration to problems of soil fertility, so that the production of clovers and the raising of live stock are advisable. Where grain is to be the chief crop of the farm, a large area of grass pastured and fed to those classes of live stock demanding a low cost for labor in their keep is the solution of the fertility problem, and the markets and economic environment of such a farm rarely justify dairying and intensely cultivated crops, such as ensilage. Likewise, in corn and potato farming on high-priced land, live stock is essential to good farm management and to the maintenance of profitable yields. Cattle and hog feeding are well adapted for combination with the corn crop, and dairying with conditions which make potatoes profitable.

Good farm management demands the application of the principles outlined in this discussion—principles which, if ignored, result in "no-profit" farming. Those conditions and factors which determine the value of land give a different environment to all grades of land, and the system of cropping and farm management, to be profitable, must recognize the environment.

NOTE: Five years after this bulletin was published (1909) the costs of producing farm crops had increased about 20% due to an increase in the costs of farm labor and feeds, as well as an increase in the rental value of land. Prices of agricultural staples also rose greatly. The author has made no attempt to revise to date the statistics used in this discussion, because the statistics are useful merely for the proof of the general argument. The general statements made in this bulletin on this subject will be as true in 1930 or 1950 as they were in 1909. Students, if they wish, may make a local problem out of this feature of farm management, by following the methods of comparison above used and substituting local crops, crop prices, and land values.

PROBLEMS AND PRACTICUMS

(1) Why is a succession of wheat, millet and oats not a real rotation of crops? Compare such a succession of crops with a succession of corn, oats and clover. Note carefully all the differences.

(2) What is the average cost of producing an acre of corn, wheat, oats, potatoes, and meadow crops in your locality? (Get suggestions about cost items from page 491 of this book, and then use local wage rates and local prices for seed, etc.)

(3) What is the marketing cost per acre in your locality for a corn crop yielding 50 bu. per acre; wheat 20 bu. per acre; oats 40 bu. per acre; potatoes 125 bu. per acre; and a timothy and clover crop yielding 3 tons per acre? Estimate the marketing costs per acre if the corn, oats, and hay crops were fed to dairy cows, fat cattle, swine or sheep. Compute these costs on the basis of local haul to the elevator or shipping point, and also the railway freight and commission charges for delivery in the terminal market that fixes the local price. See reference books on feeding farm animals.

(4) With land of equal value estimate the approximate amount of fixed and working capital necessary to the management of a 160 acre grain farm, corn farm, cotton farm, hay farm, mixed grain and stock farm, dairy farm, and sheep farm. Use local data and conditions so far as possible.

(5) What is the approximate loss of plant food on a wheat or corn farm? What is the loss of plant food on a cotton farm where the lint and seed are both sold? What loss is there when the lint is sold and the cotton seed fed to live stock? What does the loss of plant food amount to on a stock farm where all crop products are fed to the live stock? Compute these losses in percentage amounts of the amount of plant food removed from the soil by any desired combination of crops. See pages 296, 459.

(6) Prepare a man and horse labor calendar for a 160 acre farm growing 140 acres of small grain and 10 acres of pasture annually; 140 acres of corn and 10 acres of pasture annually; 140 acres of potatoes and 10 acres of pasture annually; 140 acres of hay and 10 acres of pasture annually; and a farm growing 60 acres of small grain, 30 acres of corn, 30 acres of meadow, and 30 acres of pasture annually. Estimate by months the number of men and horses necessary to properly care for the crops. Study your estimates from the viewpoint of present day farm labor conditions.

(7) Why is exclusive grain growing commonly practiced in new agricultural regions? Why does mixed farming usually supersede exclusive grain growing? What has the value of land to do with this change?

(8) What is the percentage of unavoidable crop waste with peas or potatoes on farms where there is no live stock to consume these waste products? (Get estimates from experienced local farmers.)

(9) If a storm just prior to harvest lodges small grain beyond hope of harvesting, would it pay to borrow money with which to purchase live stock to recover some value in the crop? What kind of live stock would you regard as most profitable for this purpose?

(10) How many pounds of gain can be secured from a bushel of corn when fed to hogs 5 months old? Hogs 6 months old? Hogs 8 months old? Hogs 10 months old? Hogs 12 months old? Hogs 16 months old? Using your local prices for corn and the live weight of hogs, compute the possibilities for enhancing the selling value of the corn by feeding to hogs of the ages above mentioned. Make similar computations for cattle, one, two and three years of age. (Secure information from Experiment

Station feeding investigations and from local, experienced stock feeders.)

(11) If alfalfa hay is worth $7.00 per ton in the stack what price will the hay bring if fed to two or three year old steers worth 7 cents per pound live weight? What price, if fed to good yearling wethers worth 6 cents per pound live weight? Using your local prices for alfalfa, clover, or pea hay, and for the live weight of cattle and sheep, compute the possibilities for enhancing the selling value of the hay by feeding. (Secure information from Experiment Station feeding investigations and from local, experienced stock feeders.)

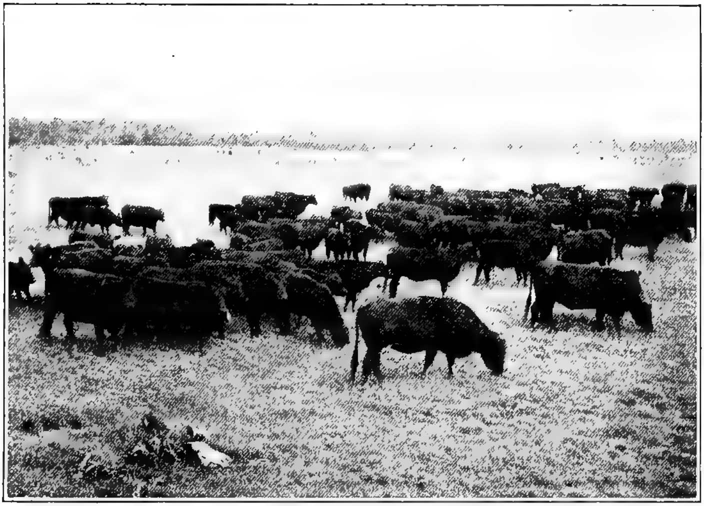


Photo by courtesy Soo Line.

Beef cattle pasturing on cut-over timber land in Northern Michigan. After the land is brushed it is easy to secure a good pasture of tame grasses and clovers from which an income can be secured while the stumps and brush roots are decaying. In these days of high prices for grass fed cattle the opening of a farm in the timber regions is comparatively easy.

CHAPTER V

FIELD MANAGEMENT TO ESTABLISH CROP ROTATION

Systematic rotation of crops is a term commonly used to mean a system of crop rotation wherein the pasture and meadow lands, as well as the grain and cultivated crops, are periodically planted on all the farm fields, and where the crops follow each other in a definite system on fields planned to meet the requirements of the rotation plan. Where mixed grain and live stock farming is practiced, as is the case on a large part of the prairie land areas of the United States, and where all areas of the farm can be made capable of cultivation, a scheme of cropping that includes rotation pastures and meadows is usually preferable to one that includes permanent pastures or meadows, because the productivity of the entire farm is more easily kept at a high level with the minimum of cost.

There are many farms in the United States, however, that cannot be planned in such a manner as to include rotation pastures. Winding creeks, stony ridges, abrupt hillsides, and bottom lands incapable of drainage, make the permanent pasture a necessity on some farms. In some agricultural regions of the United States, and with certain systems of live stock farming, the permanent pasture is preferred to the rotation pasture. On still other farms where very intensive dairy farming is practiced, pasture lands are never used, but green summer feed is provided by means of soiling and ensilage crops.

Under the conditions above noted, the so called "systematic rotation of crops," including rotation pastures,

cannot be practiced as shown in Diagram VII of this chapter. Crop rotation plans, however, that will alternate the grain, grass, and cultivated crops on the land and secure the benefits to be gained by crop rotation, can be made for farms that have conditions preventing the use of rotation pastures. Rotation plans that will meet all these conditions are shown and explained in detail in Part II, Chapter VI.

The diagrams, reorganization plans, and explanatory notes of this chapter pertain to general matters relative to field management intended to secure systematic rotation of crops under conditions favorable to use the rotation pasture. The plans of this chapter, given to illustrate methods applicable to an old farm, should be regarded merely as pertaining to a particular problem from which the reader may gather ideas about farm reorganization that will assist him to develop cropping plans for any farm.

Drainage and Land Clearing Essential to Systematic Crop Rotation. Systematic crop rotation cannot be put in operation on the entire area of any farm having lands subject to an excess of standing water at certain seasons of the year or having undeveloped wild sod land or uncleared timber lands. All areas within the farm boundaries must first be made capable of cultivation. For example, if a farm contains one field that is too wet for corn and the small grains, but will produce redtop and alsike hay, the inevitable result is that the field too wet for corn and the small grains becomes a permanent meadow or pasture, and that the other fields grow cultivated and grain crops continuously and lose the benefits of the grass or humus producing crops.

Some rotation can, of course, be practiced even under these conditions, but unless large quantities of barnyard manure are available, and unless green manure crops are used, the productivity of the entire farm cannot be made

so great as when all the fields are periodically occupied by the humus producing crops, the cultivated crops, and the grain crops. Drainage and land clearing work must precede the planning and inauguration of systematic crop rotation that will benefit all the fields of the farm, and permit systematic field management.

Photo by courtesy "The Farmer"

A ditch opened for tile drain. Wet land on a farm is usually a hindrance to the total farm revenue possible, even though the land is good meadow and pasture. When one portion of the farm grows grass continuously, the tendency is to plant grain and cultivated crops continuously on the balance of the farm, and this is eventually injurious to soil productivity.

Division of Fields. In order to make a crop rotation plan systematic and capable of producing approximately the same amounts of grain crop products, grass crop products, and cultivated crop products annually, (this being essential in giving permanency and stability to the farm business, especially where live stock is one of the farm enterprises), it is necessary that the total area of land on the farm shall be divided into three, four, five or more fields of approximately equal size. The number of fields will

of course depend on the length of the rotation, that is to say, the number of years required to make a complete cycle of the crops to be grown.

Let us take a very simple rotation as an example and explain it by means of a diagram. Suppose a rotation of wheat (grain crop), clover (grass crop), and corn (cultivated crop) has been planned. Such a rotation would occupy three years in completing its cycle and would require that the total farm area be divided into three areas of equal size. Suppose this farm contains one hundred and twenty acres of land, it would then be divided into three fields containing forty acres each, and the crops would be rotated over these fields as shown in Diagram I. For the sake of simplicity no attempt is made in this diagram to show the farmstead and lanes. This diagram is intended to illustrate the methods of systematic crop rotation and nothing more.

Diagram I. A Simple Three-Year Rotation.

	(1) 40 Acres..	(2) 40 Acres.	(3) 40 Acres.
Year 1.......	1. Wheat	1. Clover	1. Corn
Year 2.......	2. Clover	2. Corn	2. Wheat
Year 3.......	3. Corn	3. Wheat	3. Clover
Year 4.......	4. Wheat	4. Clover	4. Corn

NOTE: This rotation plan could not be put into effect immediately on any farm. One or two years of preparation would be necessary during which the field areas could be determined, fencing done if necessary for live stock, and a crop of clover seeded on one of the fields.

As soon as this preliminary work is completed the crops are grown in a regular, systematic succession of wheat, clover and corn on each field, and then when the cycle of three years is completed, wheat is again planted after the corn crop.

Each year by this plan the farm produces forty acres of wheat, forty acres of clover hay, and forty acres of corn. The fixed order of crop succession is necessary in order to have each crop grown follow that crop that will leave the soil in a desirable physical and chemical condition for the crop in question, and also that the same amounts

of wheat, clover and corn may be produced on the farm each year, and thus not disturb the permanency of the live stock enterprises of the farm business.

Further study of Diagram I will show how exactly this simple rotation follows the best principles of soil tillage and crop production. Red clover is known to succeed best in a compacted seed bed, free from weeds, and protected during its early stages of growth by a nurse crop. Clover is, therefore, seeded with the wheat and after the wheat harvest the clover gains full possession of the soil and in the succeeding year produces a heavy growth of forage. Thus no time is wasted in starting the clover crop, and the clover receives the most favorable place in the rotation for clover.

In the autumn of the second year of the rotation the clover sod is plowed under and, during the succeeding winter, time is given to decay the organic matter and crumble the soil before seeding another crop. If manure is available on the farm, it is spread, during the winter and early spring, on top of this plowed clover sod, and disked in, to prepare the land for the corn crop.

In the spring of the third year this manured clover sod is disked and harrowed smooth preparatory to corn planting. An exceedingly good seed bed is thus provided for corn. We have previously seen that corn is a gross feeding crop and capable of thriving well on land containing organic matter and raw manure. In consideration of these facts, corn is planted, following the clover sod, and is given a very favorable place in the rotation to yield its maximum product.

In the spring of the fourth year the old corn land is disked and harrowed, wheat is seeded with the added mixture of clover seed, and the three year cycle of crops is again started. Wheat, as previously stated, is a delicate feeding crop that must have large amounts of fertility easily available to produce maximum yields. No more ideal place for a wheat crop could be provided than following a corn crop grown on manured clover sod. The disked seed bed would be compact, able to supply moisture, and filled with decaying manure and clover roots that would supply available fertility. Clover also is known to start more quickly and to thrive better on soils rich in nitrogen, so that the clover crop has been considered in that it is given a place in the rotation where it may use the available nitrogen from manure and the decaying roots of a previous clover crop.

In this rotation it should be noted that the land is plowed only once in three years, and yet the crops are so arranged that a desirable physical condition in the soil is always maintained. On very weedy land it might be found necessary to plow twice in three years to keep weeds in check, for disking does not destroy weeds as thoroughly as plowing. In that event the corn land would be fall plowed in preparation for wheat, and the clover sod fall plowed in preparation for corn.

It may be seen also, from this diagram, how a rotation of this nature simplifies and systematizes the field work of the farm, distributing the labor through the various seasons and giving system and

permanency to the farm business. Apply any or all tests of the scientific principles of soil tillage, crop production, and farm management, to this rotation, and the plan of cropping is not found wanting in merit.

The rotation given in Diagram I is very simple, but it is fundamental and basic in principle. Any student who masters the principles involved in this simple plan can apply them to problems of field management and crop production of a much more complex nature. A great variety of crops exist that can be grown to advantage in the Temperate Zone, and they can be arranged in a countless variety of rotations, covering a cycle of years anywhere from three to ten years, meeting the demands for big farms, small farms, grain farms, dairy farms, or other types of farming, and still preserving the principles of crop rotation.

The Reorganization of Old Farms to Establish Systematic Crop Rotation. It usually requires several years and careful advance planning to reorganize an old farm, and to arrange the fields in such a manner as to make possible a definite, systematic rotation of crops and the most efficient use of labor and machinery in crop production. It would be a comparatively easy matter on a tract of wild, smooth prairie land, to gradually make a systematic arrangement of the fields, buildings and lanes; but the necessity for crop rotation is never realized when prairie land is broken and put into cultivation. The problems of subduing the land, the realizing of quick profits, and the establishing of a home, take precedence over plans for the systematic planning of farms for the future needs of the business.

The pioneer farmers of the United States have never been systematic in their methods of farm management. Wild land has been broken or cleared a little at a time without any thought of systematic planning for the future. As a result, the great majority of our American farms have developed in

a haphazard, unsystematic manner. Buildings, lanes, and field divisions, have been often laid out without any definite plan of arrangement or thought for the economies of farm management.

Methods and arrangements that prevailed in pioneer days have been often allowed to stand on account of the inertia in regard to tearing down the old and building anew. Fences, lanes, pastures, and farmstead arrangements that served the purpose of the pioneer, are often hindrances to systematic crop rotation and field management. Many a farm in the North Central States has a permanent pasture of native grass that is comparatively unproductive, irregularly shaped fields that cause loss of time in handling labor and machinery, and small areas that are unproductive, because they need tile drainage. These conditions are often found in regions where land is worth $75.00 to $200.00 per acre.

These are the conditions of agriculture in the United States under which systematic crop rotation and field management must usually be established. In the development of such virgin land as still remains in the United States we may expect to see a repetition of the usual pioneer methods that clear and subdue the land, crop it unsystematically, and rapidly exhaust the soil's store of available plant food. The farms are then left badly planned for the succeeding generation of farmers who realize the need and the advantage of a systematic scheme of crop production, and who are desirous of planning their tracts of land so that systematic crop rotation and field management can be practiced.

When land becomes high in value and when the wasteful methods of pioneer agriculture have exhausted much of the available fertility in soils, the necessity for systematic crop rotation and field management becomes imperative, if land is to return a fair profit on its market valuation. The

modern high land values, scarcity of competent farm labor, and the growing use of power machines for accomplishing farm work, all demand greater system in field management than was necessary in the early days of American agriculture. Losses in the handling of labor and machinery on irregular, poorly planned fields, losses from unproductive pasture lands, losses in crop values from unproductive fields resulting from long continued continuous cropping to small grains, corn or cotton, and losses resulting from investment values in undrained or uncleared lands, on which there are taxes and, possibly interest, must be checked by means of systematic crop rotation and field management if the business of agriculture is made to pay even the current rate of interest on the investment.

Systematic field arrangement is as essential a part of the business of farming as the arrangement of buildings and the distribution of power in a manufacturing establishment. When a modern factory is built, every possible consideration is given to the location of the buildings and the various divisions or departments and to the transmission of power through the factory, in order to effect all possible economies in time and power. Many an old manufacturing establishment is forced into bankruptcy by the competition of its more modern competitors that have a lower cost of production due to a more systematic arrangement of the divisions of manufacturing and transmission of power. Many an old farm in the United States, also, that has badly planned fields, unproductive pastures, waste lands, and run down soil, would go into bankruptcy, were it not for the fact that the farm gives the proprietor his board and lodging, and that the farm was homesteaded or bought in an era of low land values, and has no actual burden of carrying charges based on its present market value. But, even so, the farmer

who is operating under these circumstances is actually managing a losing business. If the farm, by reason of these conditions previously mentioned, is not paying a net profit of at least 6% on its present market value, the proprietor would find it more profitable to sell his business and invest his capital in reliable securities that will yield a dividend of at least 6%.

These methods of field management necessary to effect all possible economies in the handling of labor, power and machinery, and to realize maximum products from the soil, become apparent and essential to the generation of farmers that purchase or lease high priced land and have an actual burden of carrying charges on high priced land to figure into their accounts. To these men the economies and benefits of systematic crop rotation and field management offer the readiest and most practical methods for increasing the productivity of their farm lands, and developing a profitable system of agriculture in these days of high land values.

The reorganization of an old farm to insure systematic crop rotation and field management is a matter of farm finance to be carefully considered before the work of reorganization is begun. An outlay of capital is as necessary to this work as to the reorganization work of a railroad which contemplates the reducing of grades, the straightening of curves, the laying of heavy steel rails, and the graveling of the roadbed. The railroad manager knows that a wise expenditure of capital in such work will eventually increase the efficiency of the railroad and make possible lower operation costs and greater net profits. Similarly, in the case of farm reorganization, the outlay of capital is justifiable and productive of greater net profits, if the result will effect economies in farm management and increase the producing capacity of the farm fields.

In most cases of farm reorganization to establish systematic crop rotation and field management, it is possible to plan the work so as not to interrupt the regular business of the farm, and to pay the costs from the proceeds of the business. Wherever reorganization work can be financed in this manner, it is, of course, preferable to financing the work with borrowed capital, on account of the saving of interest.

On the other hand, there are certain conditions relative to farm reorganization where it is highly advisable to use borrowed capital to facilitate the work, and where the cost of interest on the loan is insignificant compared to the gains that may be secured through the use of ready money. An example of a situation of this nature in farm finance is where a portion of the land needs tile drainage. If a farm with forty acres of land needing tile drainage is producing less pasture than a field of similar size growing red clover and timothy or alsike clover and timothy, and if crop rotation is not being practiced on the balance of the land on account of this permanent pasture, such a field causes a loss in farm income that is greater than the interest charge on the capital necessary to drain the land and make it productive plow land. Wherever a condition of this sort exists, the use of borrowed capital is justified; for the returns from the use of such capital will exceed the interest charges several times.

If this land can be drained, for example, for $500.00, the first year's crop of flax or corn would pay for the cost of drainage. A loan of $500.00 to accomplish this work would cost but $30.00 per year at 6% interest, and $40.00 per year at 8% interest. It can readily be seen that in a case of this sort the interest charge of $30.00 to $40.00 annually is a small item as compared to the annual loss incurred by reason of the comparatively unproductive land.

Moreover, when a comparatively unproductive field of this kind is drained and put into a system of crop rotation, the chances are that the yield of all crops on the farm will be increased. Tame grass pastures will yield more feed than wet pastures, and the grain and cultivated crops will yield more, because they are in rotation with grasses and clovers.

No matter whether the farmer has capital resources of his own with which to reorganize an old farm or whether he borrows capital for this purpose, it usually requires considerable time to establish systematic crop rotation and field management. Time is necessary to change old fence lines and seed down land to tame grasses, as well as to accomplish drainage or land clearing. In planning the reorganization of an old farm, therefore, the plans should be so made as to distribute the work through several seasons and to accomplish the desired results with as little interference as possible with the regular work of the farm. By careful planning it is possible, usually, to accomplish most of the work with the regularly employed labor of the farm, and thus keep down the cost of labor to a minimum. Of course such work as drainage or land clearing requires extra labor, but the changing of fence lines and lanes, and the straightening of field lines can all be worked in at odd times with the regular farm help.

If drainage or land clearing work is to be done, it should be planned to distribute this work through as many seasons as are necessary to reorganize the balance of the fields on the farm. Thus, by the time the land is drained or cleared, the balance of the land has been systematically arranged, and, when drainage or clearing is completed, the whole farm area is ready to combine in a systematic scheme of cropping.

In Diagrams II, III, IV, V, VI, and VII, there is presented a series of plans showing how an old farm can be re-

organized and placed under a systematic scheme of cropping. This old farm chosen as an example of a badly arranged farm needing field reorganization, is located in Southern Minnesota, in a region where good varieties of corn mature, and where land values range from $75.00 to $100.00 per acre. The owner of this farm values his land at $90.00 per acre. About sixty acres of this farm are in permanent white clover and blue grass pasture that is first class pasture land, but too wet in the spring to plow unless tile drained. This pasture land is easy to tile drain and could all be put under the plow for a cost that would not exceed $600.00. The farm was homesteaded about forty years ago and has been cropped principally to small grains.

No attempt has ever been made to practice crop rotation, and very few grass crops have been grown on the plow land. During recent years the crop yields have averaged as follows: corn, forty to forty-five bushels per acre; oats, forty to fifty bushels per acre; barley, thirty to thirty-five bushels per acre; wheat, twelve to sixteen bushels per acre; and timothy hay about two tons per acre. The system of farming has been grain growing almost exclusively with not much attention given to live stock. Under the present system of farming the farm does not pay a good profit over and above the labor, seed, depreciation charges and taxes. The farm needs crop rotation and the use of live stock to raise the productivity of the old grain fields, and better arranged fields to effect economies in the handling of labor and machinery.

A discussion of the methods and plans for the reorganization of this farm in a practical manner that will not interfere with the regular farm work, and in such a manner that the work, with the possible exception of the tile drainage, can be accomplished from the annual proceeds of the business, is given in detail in notes accompanying each diagram.

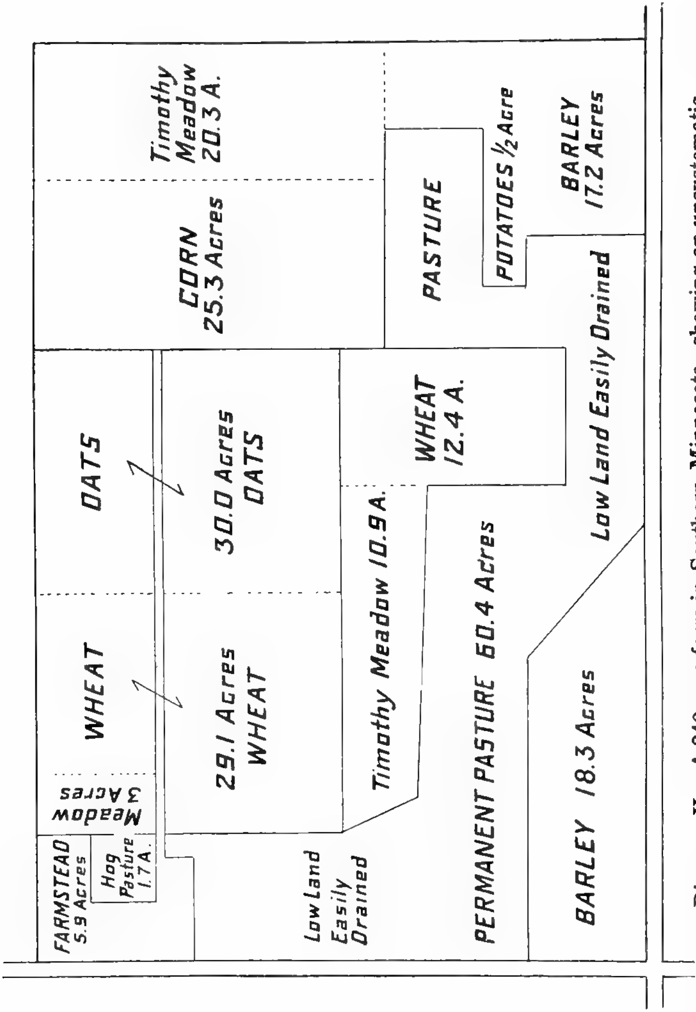


Diagram II. A 240 acre farm in Southern Minnesota, showing an unsystematic arrangement of the fields. Solid lines represent fences.

DIAGRAM II

NOTE: This diagram shows the present unsystematic and irregular arrangement of the fields, and the manner in which the permanent pasture cuts into the plow land and prevents a systematic scheme of cropping.

The buildings and farmstead are also badly located in relation to the fields, thus causing losses in field work in the management of labor and machinery. The buildings and farmstead improvements represent an investment of about $4,000.00, and, as it would disrupt business to some extent and also cause an additional financial burden on the work of reorganization to change their location, the reorganization plans will be worked out with the buildings and yards in their present situation. If a change were practical, a more desirable location, from the viewpoint of field management, would be on the other mainly traveled road, midway between the boundaries of the farm.

It may also be noted from this diagram that there are approximately 1,100 rods of old internal fencing on the farm, much of which is of little use under the scheme of cropping and field management now followed. By reference to Diagram VII, where the same farm is shown completely reorganized, it may be seen that about 1,020 rods of internal fencing are necessary to completely fence all fields of the farm, thus making every field available for regular pasture, as well as meadow aftermath, stubble, or catch crop pasture. In the diagrams of this farm the fences are represented by solid lines.

It is hardly necessary to point out the unsystematic arrangement of these fields and the inevitable waste of time that takes place in the management of labor and machinery on fields laid out as these are. The lack of system is apparent from a mere glance at the diagram. As the fields are now laid out, systematic crop rotation is impossible; many of the fields are difficult to reach from the buildings; and several fields are of such irregular shape as to hinder the use of machinery to the best advantage. That three meadows are at three different places on the farm is also a hindrance to rapid, systematic methods of handling the hay crop.

DIAGRAM III

NOTE: In this first year of reorganization the work of straightening out the fields is started with the idea of gradually changing the arrangement of the farm fields to correspond with the completed plan shown in Diagram VII. In other words, the reorganization plans must lead up to the completed plan in as practical a manner as is possible, and with as little interruption as possible to the regular farm work. The completed plan, as shown in Diagram VII, is first made, and the reorganization plans are then made to gradually lead up to this ideal plan.

This year the old timothy meadows are left undisturbed to produce hay until other land can be seeded to grass. The little three-acre meadow adjoining the farmstead has been broken up in order to straight-

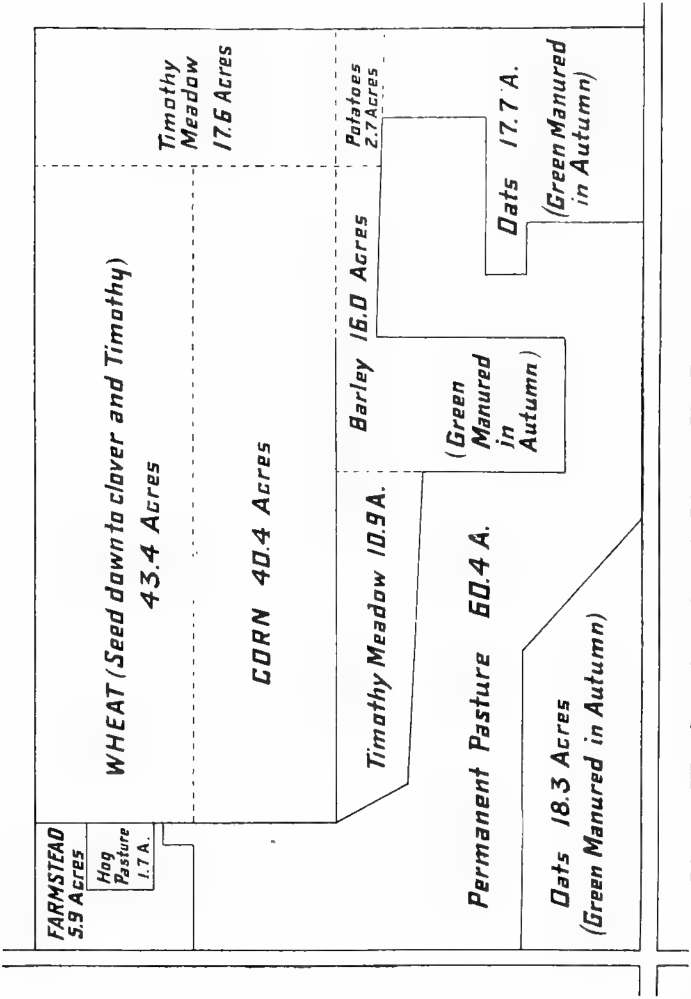


Diagram III. Same farm shown in Diagram II. Farm reorganization to establish systematic crop rotation. Plan for the first year.

en out a large field for wheat, also a small part of the largest piece of meadow land is broken up for potatoes in order to straighten out the fields for succeeding years.

The old lane fencing, from the farmstead to the corn field, on the original plan, has been torn down, also the old fence along the corn field. This old fencing is useless and in the way of the completed plan, and is, therefore, torn out to make way for the large, regularly shaped fields of wheat and corn.

The work of tile draining the old permanent pasture is started this year. If finances permit, the entire field can be drained this year. If not, part of the work can be done this year, and part next. While this work of tile draining is going on, the old pasture fence is left intact and the land used as before for pasture.

A mixture of red clover and timothy, or alsike clover and timothy, is seeded with the wheat crop in order to start new and productive meadow land, and permit the old, sodbound timothy land to be broken up the succeeding year.

After the oats and barley are harvested and stacked this year, these fields are thoroughly disked and a green manure crop of vetches, black soy beans, field peas or buckwheat sown. Another and simpler method for getting a green manure crop on these fields would be to sow mammoth clover with the grain in the spring and allow it to grow undisturbed after grain harvest. Late in the autumn the green manure crops are plowed under to enrich the soil and increase the productivity of the land until such time as the farm can all be placed under a systematic scheme of crop rotation.

The ten acre timothy field is broken up this autumn in preparation for corn. A portion of the seventeen acre timothy field is also broken in preparation for wheat, and that portion of this timothy field adjoining the new grass seeding is left unplowed in order to make a large, solid field of grass the succeeding year.

DIAGRAM IV

NOTE: This year the drainage work must be completed, unless it was finished the previous year. No old fencing needs to be torn down this year, or new fencing set, as the old pasture is still in use.

The corn land of the previous year, together with that portion of the old timothy sod that was broken, is disked in the spring of the year and seeded to wheat. Red clover and timothy, or alsike clover and timothy, are seeded with the wheat.

Meadow land is provided this year from the seeding of grass made with wheat the previous year.

Corn is planted this year on the ten-acre timothy sod land, the green manured barley land, and the potato land of the previous year.

The green manured oat land of the previous year is again seeded to oats this year.

This season an increase in the amount of live stock on the farm would be desirable on account of the large amount of corn produced

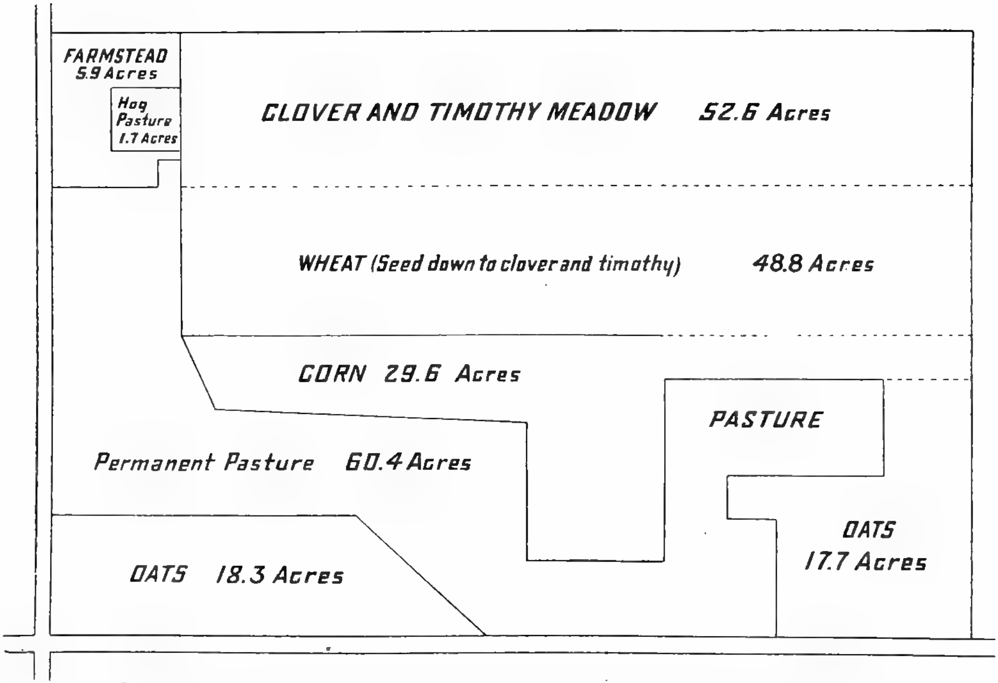


Diagram IV. Same farm as shown in Diagram II. Farm reorganization to establish systematic crop rotation. Plan for the second year.

the previous year and also on account of the increase in the amount of hay produced as compared to previous years.

In the autumn of this season a new fence would be set between the meadow land and the new seeding of grass made with the wheat. The meadow aftermath could then be used in the autumn for pasture.

As soon as this new fence is set, and the stock turned in, all of the old pasture fence is torn up as soon as possible to permit of breaking the old pasture land. The old fence along the line between the wheat and corn fields is left standing.

The oats stubble land is fall plowed, and if time permits the corn land should also be fall plowed, thus cleaning up all the plow land of the farm in nice shape. If time will not permit all this plowing to be done in the autumn, the breaking can be done, and the stubble plowing held over till the succeeding spring.

DIAGRAM V

NOTE: This year the newly fenced grass land is used for pasture and the grass seeding of the previous year is used for meadow.

The crops can be arranged on the balance of the land this year to suit the requirements of the farm as regards live stock, or in almost any manner that the farm manager desires, providing one field is set aside to seed down to clover and timothy with either wheat, oats or barley. If the farm is now carrying considerable live stock, a large acreage of corn can be planted, if desired, on the rich old pasture land. Or, if desired, wheat can be eliminated from the list of crops this year; the grass seeding done with oats or barley; a large acreage of flax sown on the old pasture; and about the same acreage of corn planted as in previous years.

The plan shown in this diagram includes wheat for the nurse crop, a field of flax on the breaking, a field of corn partly on breaking and partly on stubble ground, and two fields of oats sown partly on stubble and partly on breaking.

In the autumn of this year the fence between the meadow and the new seeding of grass is completed in order that the meadow can be used for pasture the succeeding year. Some fencing work is also done in the autumn of this year to lay out the new yards and minor rotation fields for live stock, that are shown on Diagrams VI and VII. This work can be done in the spring of the next year, but it would ease up the spring work a great deal, if part of this fencing work were done this year in the autumn months.

Considerable plowing is necessary in the autumn of this year. The pasture land is broken in preparation for corn, and the flax, oats and corn fields should be fall plowed, if possible, in preparation for the small grains to be sown the next year.

If the land that was sown to oats this year shows signs of low productivity, it can be green manured again this autumn. If the land is fertile and in good physical condition, green manuring would be unnecessary.

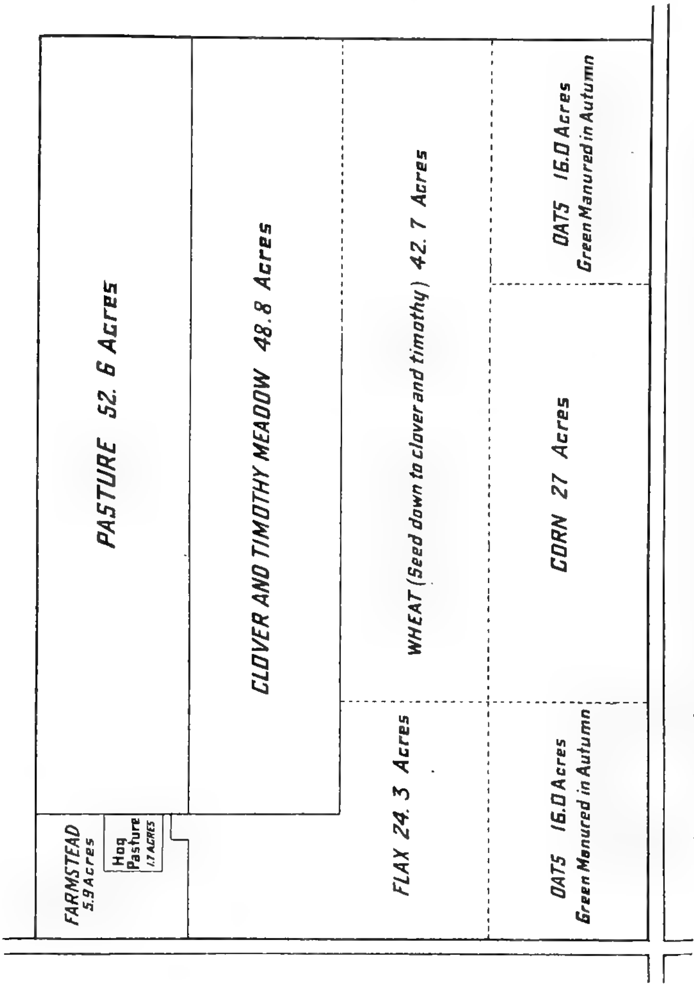


Diagram V. Same farm as shown in Diagram II. Farm reorganization to establish systematic crop rotation. Plan for the third year.

DIAGRAM VI

NOTE: All the preliminary work necessary to the establishment of a systematic rotation of crops has now been accomplished. All areas are now under plow, the field lines have been straightened out, new seedings of grass made for pasture and meadow, and the fields so planned as to be easily accessible from the buildings and to conserve time and power in the field operations. A systematic rotation of crops is now possible and can begin this year.

A comparison of this diagram with Diagram II, will reveal the many advantages secured through having the fields laid out in a systematic manner. In the first place systematic crop rotation will undoubtedly raise the productivity of the old grain fields, increase the acre production of hay as compared with the old, sodbound timothy meadows, and the shifting of the pasture land from one field to another will enrich the fields from the manure dropped by live stock. In the second place, man labor, horse power, and machine capacity for work will be more efficient on these fields than on the irregularly planned fields of Diagram II.

Any man who has ever handled horses and farm machinery knows the advantages of using four or six horse teams and large capacity machines, as compared with two or three horse teams and small capacity machines. He also knows that small, irregularly shaped fields cause poor tillage work, weed accumulation, and loss of time in the handling of horse power and machinery. The large, straight lined field facilitates work with the gang plow, the harrow, the binder and the mower, and, also, during the rush seasons of seeding and harvest, permits the concentration of the labor crew on a large piece of work with no shifting about from one little field to another. All these features of farm management are items of consequence in keeping down the costs of production on farms, and, therefore, in securing the maximum net profit. In fact, they are items that cannot be ignored in these days of high wages and scarcity of farm labor.

If the farmer, nowadays, expects to secure competent labor, he will be forced to pay as high wages for competent help as are paid by the railroads and manufacturing establishments. It takes ability to handle a four horse team and a gang plow, binder or potato digger, and men having this ability will have to be paid as high wages as they could secure in industries other than agriculture. These conditions relative to American labor must be realized and squarely faced by the American farmer. If high wages must be paid, labor must be made correspondingly efficient, and to make labor efficient, large teams, large capacity machines, and a systematic field arrangement must be used. Labor cannot be used efficiently on small, irregularly shaped unsystematically arranged fields. On small farms where intensive agriculture is practiced, the use of large capacity machines and big teams is impractical, but systematic field arrangement facilitates the field work whether the farm be large or small.

Four small fields of about four acres each are laid out this year adjoining the farmstead. These fields are all fenced with hog tight

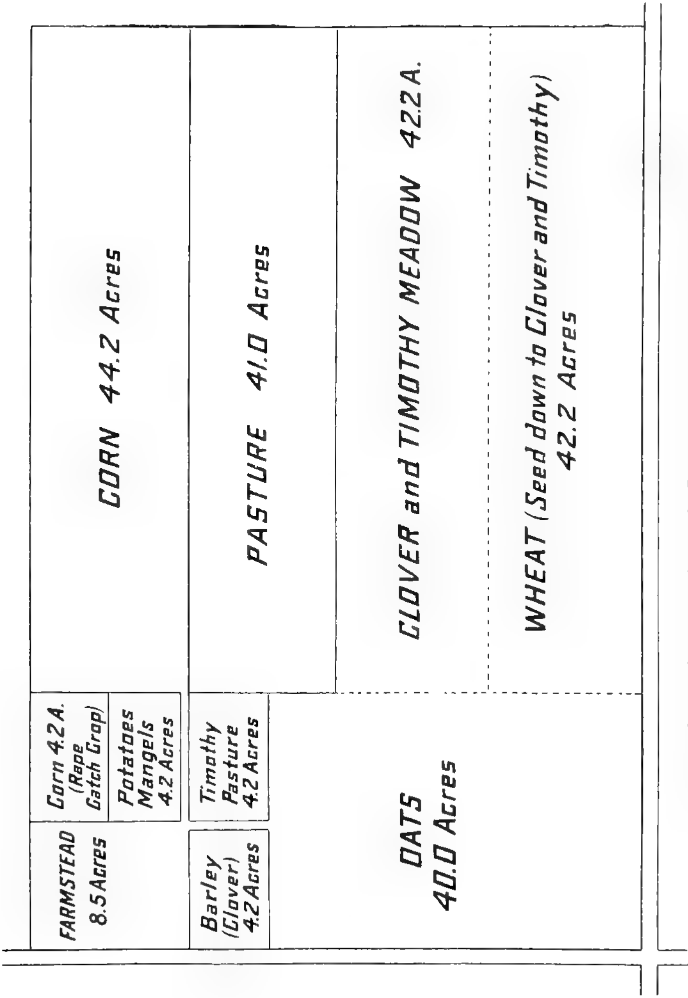


Diagram VI. Same farm as shown in Diagram II. Farm reorganization to establish systematic crop rotation. Plan for the fourth year.

fence, so that they can be used alternately for hog pasture. A four year rotation of crops is started this year on these small fields, crops being chosen that will mainly be used for pasture and feed for live stock. This year a portion of the new pasture land is included in these fields, and the corn and root crops are planted on pasture sod broken the previous autumn. A discussion of this four year rotation and the use of these small fields is given in the notes accompanying Diagram VII. A comparison of these fields with the farmstead conditions shown in Diagram II will reveal the many advantages this plan has for hog feeding and the care of young stock.

A five year rotation of crops is begun this year on the five large fields. This rotation and the manner in which the crops are rotated are discussed more fully in the notes accompanying Diagram VII.

In the autumn of this year the oat stubble land is plowed, and the pasture land is broken in preparation for corn the succeeding year. Among the small fields, plowing is done this autumn on the corn and pasture lands.

DIAGRAM VII

NOTE: In the early spring season of this year all fencing is completed that was not finished the previous autumn. Lane fences are also completed to make all the fields easily accessible to the farmstead.

A headland of grass, about one rod wide, is laid out around all the large fields. This plan can be easily carried out by leaving a headland of grass in the pasture fields, when the pasture land is plowed each year in preparation for corn. Thus, as the pasture land is rotated from one field to aother, the headlands can be laid out without any special work.

Grass headlands keep out weeds along the fence lines, provide turning ground for machinery, and make land productive that is usually waste land. It is always impossible to crop every foot of land within the farm boundaries, especially so if land is cross fenced, and if it is planned to use four horse teams and large capacity machines. There is always some waste land along the fence lines and where turning ground is necessary for machinery. This waste land, if it is in grass, prevents weeds from accumulating along the fence lines. It can be mowed for hay, and will also provide a little pasture in the autumn season when stock is running over the grain stubble or cornstalk land.

Diagram VI shows the farm completely reorganized for a major rotation of crops on the five large fields, and a minor rotation of feed and pasture crops on the four small fields. The systematic scheme of cropping begins with Diagram VI where the various crops of the rotation, as shown in Diagram VII are started on the various fields in conformity with the field conditions prevailing during reorganization. Diagram VII is really the second year of the rotation plan. In Diagram VII the plan of rotation cropping is projected on each field for five years, in case of the major rotation, and for four years in case

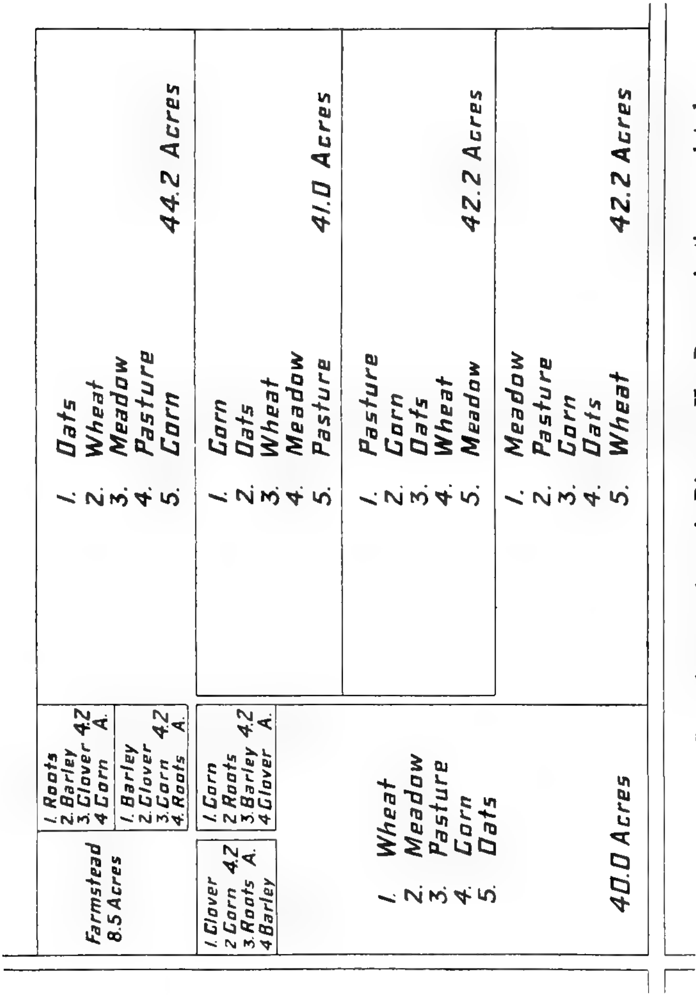


Diagram VII. Same farm as shown in Diagram II. Reorganization completed, and systematic crop rotation established.

of the minor rotation, after which periods of time the rotations begin again with the crop numbered one on each field.

The major rotation of corn, oats, wheat, meadow and pasture, occupies five years in completing its cycle on any given field, and these crops follow each other in the order named on each field. Thus each year the five large fields produce approximately forty acres of corn, forty acres of oats, forty acres of wheat, forty acres of meadow, and forty acres of pasture. Each field is plowed twice in five years, once when the pasture land is broken for corn, and the second time when the oat stubble is plowed for wheat. The oat crop would be sown on disked corn land.

The crops in this major rotation can be changed somewhat from this plan according to the amount of live stock kept and fed on the farm. If desired, wheat may be eliminated entirely from the rotation, oats or barley used for the grain nurse crop, and a second crop of corn planted where oats are sown in this plan. In this event the land would be plowed twice in five years, each time in preparation for corn, and the grain crop would be sown on disked corn land. If this rotation were planned with two crops of corn instead of two grain crops, a larger number of cattle and hogs could be fattened than otherwise. As the rotation is now planned, it is a plan for mixed grain and live stock farming. The amount of pasture land in this rotation can be increased, if desired, by sowing rape, clover, or vetches with the oat crop, or with the corn at its last cultivation, thus providing autumn pasture.

The minor rotation of corn, roots, barley and clover, occupies four years in completing its cycle on any given field, and the crops follow one another in the order named. Thus each year the four small fields produce approximately four acres of corn, four acres of roots, four acres of barley, and four acres of clover pasture. Each field is plowed twice in four years—in preparation for the corn and root crops. The land in roots is spring disked for barley. Rape is sown with the corn at its last cultivation, and when the corn crop is mature, hogs are turned in to "hog off" the corn and the rape. The clover field is used as pasture for sows and young pigs. Either potatoes or mangels can be planted for the root crop.

As these diagrams are intended to show principally the methods for reorganizing an old farm, and establishing systematic crop rotation, no further discussion of these rotations is given here. A more detailed discussion of a rotation plan similar to this one is given in Part II., Chapter VI., Diagrams IX and XII.

The total cost of drainage, fencing, and field reorganization on this farm would not exceed $1,200.00, or $5.00 per acre, and this cost could be distributed through three or four years. Would the investment pay? There is no question about it. The investment of $1,200.00 in this

kind of work would increase the overhead costs, or carrying costs, in the management of this farm by only \$72.00 (6% on \$1,200.00). Thus, if the farm is now made to pay but \$72.00 additional income each year, the investment is justified. But the systematically arranged fields, crop rotation, and more extensive use of live stock, would do far more than this. The systematic field arrangment would undoubtedly effect, at the least, a 10% saving in the costs of crop production, and, within a few years, after crop rotation and the greater use of live stock had been started, the productivity of the land would increase at least 25%, and in all probability 50%.

Furthermore, it is conservative to say that a systematically planned farm, as this farm would be when reorganized, would have a market value 20% to 25% higher than when in an unsystematically planned condition. The farm would look better and more productive and would, therefore, sell better. The investment of \$5.00 per acre in such wórk as has been outlined in these diagrams, would add fully 20% to the selling value of the property. It is improvement and productivity that appreciate land values. Prairie land newly broken will always sell for more than wild prairie land by more than the cost of breaking. Similarly, the reorganization and improvement of an old farm will give it a market value that will far more than compensate for the costs. The man who has the business judgment and the ability to improve and systematize an old farm gets ample financial rewards for doing such work in advance of the average progress in his community.

PROBLEMS AND PRACTICUMS

(1) What is the cost per rod of laying tile drain? (Get local prices on tile and estimates of amounts of labor necessary to open a ditch at a given depth, say two feet, and to lay and cover the tile.)

(2) What is the cost per acre for tiling a 20 acre field with laterals two rods apart, and with the tile laid at an average depth of two feet?

(3) If necessary to borrow money with which to accomplish tile drainage what would the interest charge amount to annually on the costs computed for question (2)? How many crops of corn, wheat, flax, or oats, at average yields and prices, would be necessary to pay for the costs of drainage computed in question (2)?

(4) When wheat is worth 70 cents per bushel how many bushels must be grown on an acre of land to pay a net profit of 6 per cent on land valued at $100.00 per acre? How many bushels of corn, when corn is worth 50 cents per bushel? How many bushels of potatoes, when potatoes are worth 40 cents per bushel? See page 490.

(5) Draw a diagram of your home farm, or some farm that you are familiar with. Draw this diagram to scale and from an actual survey of the fields. Show all field boundaries, fence lines, lanes, arrangement of buildings, feed yards, and paddocks, streams, rough land, land needing drainage, and the crops growing on the land in the year the survey was made. Determine the number of rods of fence and the acreage of pasture land. Invoice the live stock, horses required to perform farm work, and the machinery used in operating the farm. Estimate the amounts of grain, forage, and pasture annually needed to support the live stock enterprises of the farm, if a stock farm. Ascertain all facts about land value, markets, and labor, that would influence the planning of the most successful type of farming possible.

CHAPTER VI

PLANS AND DIAGRAMS

General Nature of the Farm Business. The crops to be grown and their arrangement in long or short cycle rotations must be determined by the size of the farm, the general nature of the farm business, the personal preferences of the farm manager, the character of the markets, and the local conditions of soil and climate. For example, if a rotation is to be planned for a farm, the chief business of which is grain production, the annual acreage devoted to grain crops should be as high as possible, and the acreage of grass crops as low as may be permitted by the principles of crop rotation. In case of a dairy and hog farm the annual proportionate acreage of forage and pasture crops would, of necessity, have to be higher than on a grain farm, and the annual proportionate acreage of grain crops less. The annual acreage of the grain, grass and cultivated crops must be determined by the general nature of the farm business to be followed, whether grain growing, dairying, beef and pork production, potato growing, cotton growing, the production of sugar beets, or other type of farming.

Short Cycle Rotations and the Kind of Farms to Which They Are Adapted. Short cycle rotations, or those in which a given number of crops are rotated over a given area of land in a comparatively short period of time (three to five years), are best adapted to those farms the main policy of which is to produce large amounts of dairy produce and pork, potatoes, sugar beets or cotton. Farms so managed require intensive cultivation, and are usually small in area, because the amount of land that a proprietor may successfully

manage in these types of agriculture is small. Diagrams are given herewith to exhibit rotations on farms where dairy products and potato or sugar beet products are to be the chief sources of farm income. These diagrams, as well as all other diagrams in this chapter, are not actual farm plans intended to show the complete arrangement of fields, lanes and farmstead on a farm, but are merely simple diagrams intended to show how a combination of various crops may be systematically rotated over a given area of arable land.

Diagram VIII. Rotation Plan for a Dairy Farm of 80 Acres.

(1) 20 Acres	(2) 20 Acres	(3) 20 Acres	(4) 20 Acres
1. Corn	1. Oats	1. Meadow	1. Pasture
2. Oats	2. Meadow	2. Pasture	2. Corn
3. Meadow	3. Pasture	3. Corn	3. Oats
4. Pasture	4. Corn	4. Oats	4. Meadow
5. Corn	5. Oats	5. Meadow	5. Pasture

NOTE: Each year this rotation would provide twenty acres of corn, twenty acres of oats, twenty acres of new meadow land, and twenty acres of pasture. It would occupy four years in completing its cycle, and the farm would have to be divided into four fields of nearly equal size. The land would be plowed once in four years, the pasture land being broken up for the corn. The corn land would be prepared for oats by thorough double disking. On a farm where it is necessary to give consideration to weed eradication the land could be plowed in preparation for oats as well as for corn. Barnyard manure would be distributed on the pasture lands in preparation for the corn crop following the pasture sod. Eventually it would be desirable to fence all the fields so that a full use of meadow aftermath and catch crop pastures would be possible.

This rotation would be most practical for a dairy farm where the main business of the farm is the production of dairy products. It could also be used for a farm producing various kinds of live stock products. It should be noted that the annual product of grain and grass crops is such (one half the farm area in grass crops and one half in grain crops) that, if the pasture be fully stocked, the grain and hay yield will be just about sufficient to winter the live stock and keep the milch cows well fed. The profits from the farm would, therefore, have to arise from the sale of milk or other animal products.

Diagram IX. Rotation Plan for a 120 Acre Dairy and Hog Farm.

(1) 24 Acres	(2) 24 Acres	(3) 24 Acres	(4) 24 Acres	(5) 24 Acres
1. Corn	1. Corn	1. Oats	1. Meadow	1. Pasture
2. Corn	2. Oats	2. Meadow	2. Pasture	2. Corn
3. Oats	3. Meadow	3. Pasture	3. Corn	3. Corn
4. Meadow	4. Pasture	4. Corn	4. Corn	4. Oats
5. Pasture	5. Corn	5. Corn	5. Oats	5. Meadow
6. Corn	6. Corn	6. Oats	6. Meadow	6. Pasture

Note: Each year this rotation would provide forty-eight acres of corn, twenty-four acres of oats, twenty-four acres of hay land, and twenty-four acres of pasture land. The land would be plowed twice in five years, both times in preparation for the corn crop. The oats would be sown on disked corn land. Manure would be spread on the pasture sod prior to the first corn crop. This rotation would occupy five years in completing its cycle, and the farm area would have to be divided into five fields of nearly equal size. This rotation would be most practical for dairy and hog production on farms of one hundred to one hundred and sixty acres in size. On farms of larger size it would be a practical rotation for mixed grain and live stock farming, with beef cattle, sheep, and swine.

It may be noted that in this rotation the proportion of grain and grass crops has changed from the proportion shown in Diagram VIII, and that three fifths of the farm area is devoted to corn and oats (grain) and two fifths to grass crops. The surplus of corn produced in this rotation, above what is needed for feeding the cows, could be profitably fed on a dairy farm to pigs. Thus the entire rotation is well adapted for a small dairy and hog farm.

Diagram X. Rotation Plan for a Potato or Sugar Beet Farm of 120 Acres.

(1) 30 Acres	(2) 30 Acres	(3) 30 Acres	(4) 30 Acres
1. Barley	1. Clover	1. Early potatoes (Green manure)	1. Late potatoes
2. Clover	2. Early potatoes (Green manure)	2. Late potatoes	2. Barley
3. Early potatoes (Green manure)	3. Late potatoes	3. Barley	3. Clover
4. Late potatoes	4. Barley	4. Clover	4. Early potatoes (Green manure)
5. Barley	5. Clover	5. Early potatoes (Green manure)	5. Late potatoes

NOTE: Each year this rotation would produce sixty acres of potatoes or sugar beets, thirty acres of clover hay, and thirty acres of barley for feed. It would occupy four years in completing its cycle and the farm area would have to be divided into four fields of nearly equal size. The land would be plowed twice in four years, each time in preparation for the potato crop. The barley would be sown on the potato land, disked.

This rotation is not as symmetrical and as scientific as those given in Diagrams VIII and IX, but it is practical for farms engaged in growing potatoes or sugar beets as the main product of the farm. The number of live stock that could be kept on a farm practicing this scheme of cropping would not produce enough manure to cover one fourth of the farm area annually, as should be done. Manure and commercial fertilizers might have to be purchased to keep up the productivity of some soils where a rotation of this kind is practiced. If so, the expense would be fully justified on a farm where the main products have as high value per acre as potatoes or sugar beets. Animal manures would be applied to the clover sod in preparation for early potatoes. Manure for potatoes should not be applied when freshly voided, but only when well rotted in compost heaps.

If potatoes are the chief crop to be considered, a green manure crop could be introduced between the successive potato crops. Early potatoes could be grown the third year of the rotation, and after harvest a green manure crop sown and the foliage plowed under late in the autumn. The crop the fourth year would be late potatoes, thus distributing the hard work of potato harvest through two seasons, and also placing the crop on the market at two different seasons.

In the case of sugar beets it would be impossible to introduce a green manure crop between the two successive crops, but the second crop of clover could be plowed under for green manure, thus adding an additional amount of humus and nitrogen to the soil, as compared to plowing under the stubble and roots of the clover crop after harvesting the second crop of hay.

Long Cycle Rotations and the Kind of Farms to Which They Are Adapted. Long cycle rotations, or those where a given number of crops is rotated over a given area of land in a comparatively long period of time (five to ten years), are best adapted to systems of farming where the farms are

large (at least 240 to 320 acres), and where it is desired to make small grain the chief marketable product. Rotation under these conditions is simply planning a few checks on the evils of continuous grain cropping. The plan and purpose of the farm is still to produce marketable grain, but to recognize the fact that continuous grain cropping is disastrous in the long run, and that the grain crops may be alternated with grass and cultivated crops to the advantage of the entire farm business.

Wherever small grain production is to remain the prominent feature of the farm business, live stock enterprises must be subordinated to the main line of work and be considered merely as adjuncts of benefit in the support of the greater enterprise. The grass crops necessary to a successful rotation are not usually sources of profit to the farm, in the grain growing districts, unless live stock is used to manufacture salable products from the grass and to return all waste matter to the land in the form of manure. This function of live stock in successful agriculture can be cheaply managed on the grain farms by pasturing sheep and young cattle and selling them prior to the fattening period. Some income is thus secured from the grass lands with little outlay for labor and housing, and the grass roots and manure are of incalculable benefit in maintaining profitable yields. Grass crops may be grown on grain farms for their seed value and the land will receive some benefits as regards humus and nitrogen. In such case, however, the benefits to the land are not so great as when the grass crops are pastured.

Long cycle rotations are best adapted to grain farming, because it is possible to divide a farm into seven fields, for example, and to have four of these fields produce grain each year (four sevenths of the farm area) without destroying all semblance of systematic crop rotation. In short cycle

rotations it is very nearly impossible to plan a practical combination of the grain, grass and cultivated crops, and devote more than two fifths or one half of the farm area to small grain crops annually. This fact becomes apparent from Diagrams XI and XII.

Diagram XI. Rotation Plan for a Grain Farm of 640 Acres.

(1) 91.4 A.	(2) 91.4 A.	(3) 91.4 A.	(4) 91.4 A.	(5) 91.4 A.	(6) 91.4 A.	(7) 91.4 A.
1. Corn	1. Wheat	1. Wheat	1. Meadow	1. Pasture	1. Wheat	1. Oats
2. Wheat	2. Wheat	2. Meadow	2. Pasture	2. Wheat	2. Oats	2. Corn
3. Wheat	3. Meadow	3. Pasture	3. Wheat	3. Oats	3. Corn	3. Wheat
4. Meadow	4. Pasture	4. Wheat	4. Oats	4. Corn	4. Wheat	4. Wheat
5. Pasture	5. Wheat	5. Oats	5. Corn	5. Wheat	5. Wheat	5. Meadow
6. Wheat	6. Oats	6. Corn	6. Wheat	6. Wheat	6. Meadow	6. Pasture
7. Oats	7. Corn	7. Wheat	7. Wheat	7. Meadow	7. Pasture	7. Wheat
8. Corn	8. Wheat	8. Wheat	8. Meadow	8. Pasture	8. Wheat	8. Oats

Diagram XII. Rotation Plan for a Mixed Grain and Live Stock Farm of 640 Acres.

(1) 128 A.	(2) 128 A.	(3) 128 A.	(4) 128 A.	(5) 128 A.
1. Corn	1. Oats	1. Wheat	1. Meadow	1. Pasture
2. Oats	2. Wheat	2. Meadow	2. Pasture	2. Corn
3. Wheat	3. Meadow	3. Pasture	3. Corn	3. Oats
4. Meadow	4. Pasture	4. Corn	4. Oats	4. Wheat
5. Pasture	5. Corn	5. Oats	5. Wheat	5. Meadow
6. Corn	6. Oats	6. Wheat	6. Meadow	6. Pasture

NOTE: Comparing Diagrams XI and XII, it may be seen that the rotation plan in Diagram XI provides small grain for four sevenths (365.7 acres) of the farm acreage annually, and five sevenths (457.1 acres), if the corn crop is matured for grain; while the plan shown in Diagram XII provides small grains for two fifths (256 acres) of the farm acreage annually, or three fifths (384 acres), if the corn crop is included as grain. The rotation plan shown in Diagram XII is undoubtedly more scientific and better adapted to keep soil in a good physical condition, and to freely release the plant food of the soil, than the rotation plan in Diagram XI. Diagram XII is not a practical plan, however, for a grain farm, and is better adapted for use in mixed grain and live stock farming. The larger area of grass land in Diagram XII requires more live stock to be kept on the farm, and the chief product of the farm becomes live stock rather than grain.

Diagram XI exhibits a rotation plan that is decidely practical for grain producing farms. The humus producing crops and cultivated crops are so alternated with the grain crops as to be in accord with the principles of crop rotation, and, if manure is added to the fields twice during the seven-year cycle on the corn land and pasture land, high productivity could be maintained for many years.

A green manure legume crop could be sown after the oat harvest in the seventh year of the rotation, and prior to the corn crop, or a seeding of mammoth clover made with the oats in the spring of the year and the clover vegetation plowed under, thus adding an additional supply of humus and nitrogen to the soil.

There is absolutely no question that the total annual amounts of grain sold under this system (four sevenths of the land in small grains) would exceed the sales of small grain from an equal area of land where continuous grain cropping was practiced. Such a statement refers, of course, to old land and not to land fresh from the breaking plow.

This rotation shown in Diagram XI would occupy seven years in completing its cycle and the farm area would have to be divided into seven fields of nearly equal size. Each field would have to be plowed four times in seven years, as follows: old oat stubble plowed in preparation for corn, wheat stubble plowed for succeeding wheat crop, pasture land plowed for wheat, and the wheat stubble of this crop plowed in preparation for oats. Manure would be applied on the land prepared for the corn, and also on the pasture land, providing experience had shown that wheat could be grown without lodging on a pasture sod. The corn crop could be grown for grain or for fodder according to whether or not the climate is favorable for corn.

This rotation, Diagram XI, would be improved by growing corn two years in seven, placing one corn crop after the pasture land and another, as now placed, between the oats and the wheat. Such a change is practical, of course, only in climates where the summer growing season is long enough to mature corn thoroughly.

In countries where flax seed is a valued product, flax would be the most profitable crop to be grown on the pasture land sod in the sixth year of this rotation.

Rotations for General Live Stock Farming. The rotation plan shown in Diagram XII is as well adapted to general live stock farming as any that can be formulated. The amount of grain and corn produced annually by such a rotation plan is more than sufficient to maintain and fatten the numbers of live stock that could be supported by the grass lands. This surplus of grain could be sold or used in fattening and finishing cattle, sheep, and hogs, purchased to fatten, as the proprietor chose. Such a plan is well balanced, elastic, and

well suited to use on farms where it is desired to grow cattle, sheep, and hogs, as well as to produce some grain for sale. By comparing this plan with Diagram VIII it may be seen that the proportion of corn and grain to grass land in Diagram XII is somewhat higher than in Diagram VIII, while a comparison with Diagram XI shows that Diagram XI has a greater proportion of grain crops to grass crops than Diagram XII. The plan of cropping in Diagram VIII is intended for intensive dairy farming; Diagram XI for a grain selling farm; while the crops in Diagram XII are so adjusted as to make the rotation adaptable for several kinds of general live stock farming, or for mixed live stock and grain farming.

Minor Rotations for Live Stock Farms. The term "minor rotation" is applied to groups of crops that are specially

Photo by courtesy "The Farmer."

Pumpkins, planted with corn in minor rotation fields near the buildings and feed lots, are a valuable food to supplement corn and other grain in the fattening of hogs.

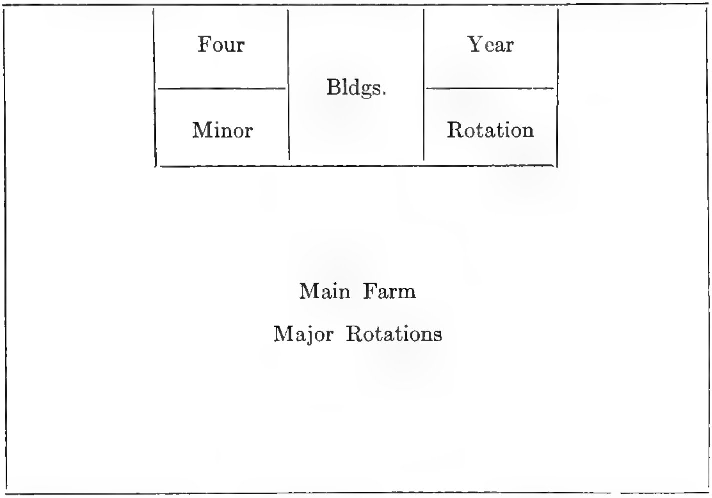
grown for the purpose of providing summer soiling crops for cattle, ensilage crops, root crops for winter feeding, summer pasture for young pigs and brood sows, and early spring and late fall pasture for sheep, cattle, and pigs. The crops most widely used for these purposes are corn, mangels, red clover, field peas, cowpeas, vetches, rape, and winter rye. Pumpkins, also, when planted with corn in minor rotation fields, will provide a large amount of valuable food for hogs during the fattening period of late autumn. The term "minor rotation" is applied to these groups of crops to signify that they are of minor importance to the total interests of the farm as compared with the large fields of staple crops, groups of which are called "major rotations."

It is practically impossible to successfully organize a dairy or general live stock farm without making some provision for small fields of pasture and soiling crops. Often these crops are planted in a haphazard manner and yield only a fraction of what they would if systematically cared for in a rotation plan. These minor rotations should be used on fields adjoining the farm buildings, so that live stock can be quickly turned out to pasture in the fields, or forage can be quickly hauled to the feeding lots.

Minor rotation fields, sown to various legume crops, have special pork-producing value at a minimum of cost. Clover, alfalfa, field peas, soy beans and cowpeas, provide nutritious feed for hogs that they will pasture off at no expense for harvesting and feeding. Hogs grown on these crops, with some slop feed, arrive at the final fattening period with good bone and muscle produced at low cost compared with pen feeding. Field peas, corn, or peanuts, matured in the field, may also be "hogged off" for fattening.

A few plans are given herewith with Diagram XIII that illustrate the methods of grouping crops in minor rotations.

Diagram XIII. Minor Rotation Plans for Live Stock Farms.



Plan No. 1
1. Corn (Rape)
2. Barley and Oats Pasture (Rye)
3. Rye (Clover)
4. Clover Pasture

Plan No. 2
1. Corn (Rye)
2. Rye (Clover-Timothy)
3. Meadow and Pasture
4. Pasture

Plan No. 3
1. Corn (Rape)
2. Barley (Clover)
3. Clover Pasture
4. Mangels

Plan No. 4
1. Barley and Oats (Rape)
2. Field Peas (Rye)
3. Rye (Rape)
4. Corn (Rape)

Plan No. 5
1. Barley (Clover)
2. Clover Pasture
3. Corn (To be hogged off)
4. Corn (To be hogged off)

NOTE: The principal idea usually involved in making up a minor rotation is to provide pasture for young cattle, young pigs, brood sows, and colts, through as many seasons of the year as possible. A specialized business, such as dairying, might demand the extensive use of these fields for soiling crops, silage and root crops, while one such as pork production would demand as much clover pasture as possible, and corn and rape for fall feed in the fattening period. In regions where alfalfa will stand pasturing one or two small fields of this crop in the minor rotation are of unexcelled value for pasture for growing swine.

Five plans are shown in connection with Diagram XIII that could be used for general live stock farms, or dairy and hog farms. A description of Plan Number 1 will be sufficient to show how such a rotation plan would be used to greatest advantage.

1st Year. Corn planted medium thick. At the last cultivation rape is sown among the corn plants at the rate of about three pounds per acre. The corn could be cut for summer soiling, for ensilage, or allowed to mature as pasture for fattening pigs, sheep or cattle. In either case the rape would provide pasture for fattening pigs or young cattle until late in the autumn.

2nd Year. Barley and oats seeded in spring and used as pasture for brood sows and pigs and young cattle during the early summer.

Photo by courtesy Missouri Agricultural Experiment Station.

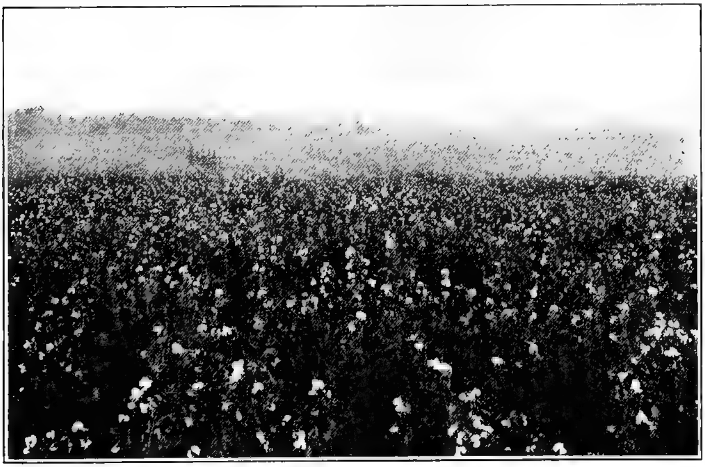
Cowpeas, used for hog pasture, are a valuable factor in producing cheap pork in regions having a favorable climate for this crop.

In late summer seed winter rye and pasture it until the middle of autumn, when it should be allowed to grow and strengthen its roots for the approaching winter.

3rd Year. Pasture the winter rye, if the stand is vigorous, until late spring and then allow the crop to mature its seeds. After spring pasturing on the rye, clover and timothy are seeded among the rye plants, and after the rye harvest the grass crop is allowed to occupy the land till winter with little or no pasturing.

4th Year. The clover and timothy are pastured all summer and fall by brood sows and pigs, or young cattle, and plowed up late in the autumn in preparation for the succeeding crop of corn.

The Use of Catch Crops in the Rotation. Catch crops have been defined and explained in previous paragraphs as those crops that may be sown in a rotation to take the place of regular, staple crops that have failed on account of unfavorable climatic conditions, or as crops that may be sown with regular crops, or between the seasons for regular



Canadian field peas. A valuable legume crop in northern climates for grain, forage, hog pasture or green manure. Field peas may be used as a "catch crop" to substitute for injured clover crops in the rotation.

crops as supplementary pasture for live stock, or to produce a second marketable crop in one growing season.

The American farmer has never made a wide use of catch crops in his scheme of farming, principally because American agriculture has been mainly conducted by extensive rather than by intensive methods, catch crops fitting better into intensive rather than extensive schemes. In many regions of China, for example, where the most intensive kind of farming is practiced, the Chinese farmers have become highly proficient in the use of catch crops, and land is thus made to produce several crops in a season. Such crops as buckwheat and turnips are used to occupy the land after a crop of barley has been taken off, or soy beans are planted between the hills of sorghum plants and harvested after the sorghum crop is removed from the land. By such methods as these the Chinese farmer keeps his land producing crops at all growing seasons of the year.

In some agricultural regions of the United States, such as the groups of South Central and South Atlantic states, the long growing season permits several crops to be easily grown on the same piece of land in one year, but in the North Central, North Atlantic, and North Pacific Coast states, the schemes of farming that have developed have never made a wide use of the catch crops. One crop a year is the more common rule. In many regions of the North Central states, in particular, land is idle from the time of small grain harvest until winter. In these regions such crops as corn, potatoes, roots, and clover must occupy the land for the entire growing season to mature the crop; but in the case of the small grains, especially barley and rye, a considerable part of the growing season remains after the normal harvest. Here, then, is a chance to introduce catch crops into the rotation and to increase the total products.

Catch crops can be used to greatest advantage in the North Central states in increasing the amount of autumn pasture on farms. Regular pastures often become short in late summer and autumn, and the catch crop pasture can then be used to keep live stock growing or to keep milch cows from shrinking in their milk production. The catch crops most widely used for this purpose are rape, sown with the grain in the spring, or either mammoth or red clover sown with the grain in the spring, and pastured in the autumn. Field peas, millet, and the vetches can also be used in some regions by seeding after the grain harvest. Winter rye, if sown early, will also produce some pasture in the autumn. The choice of a crop for this purpose depends on the local conditions regarding adaptability of the crop to climate,

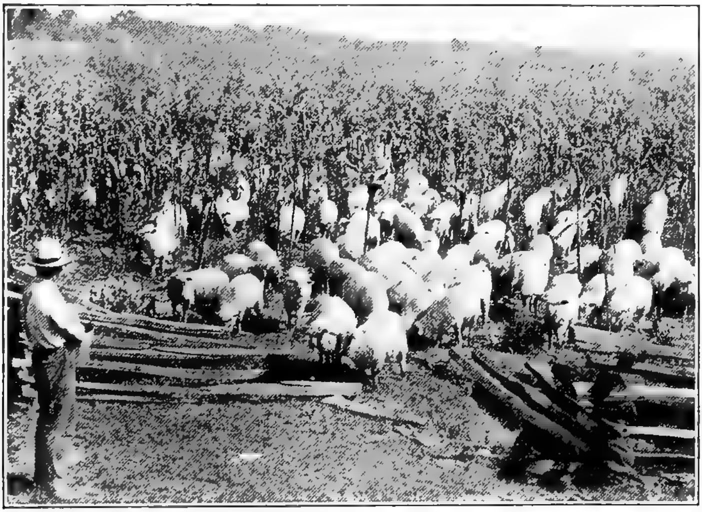


Photo by courtesy "Breeders' Gazette."

Western lambs fattening on corn and soy beans in Indiana. The soy beans are sown with the corn at the last cultivation and both crops fed off in the field in the autumn.

the price of the seed, and the kind of live stock to be pastured on the catch crop.

Buckwheat and turnips are two quick maturing crops that can be used to advantage as catch crops to follow small grains in the same growing season. In many regions of the North Central states, thoroughly disked grain stubble land will produce a good crop of buckwheat before winter. If turnip seed is merely scattered and then harrowed in on summer plowing after a grain crop, an excellent sheep pasture can be provided for late autumn. A turnip pasture is the finest feed available for old ewes after the lambs are taken away in the autumn.

Catch crops, according to the definition previously given, are sometimes planted to take the place of regular crops that have frozen out. If a grass crop, for example, is frozen out by a severe winter, some crop must be planted the succeeding spring to take the place of the meadow land in the rotation that would have furnished forage for the succeeding winter. Canadian field peas, mixed with oats, make a good catch crop for a case of this sort. The crop can be cut and cured for hay and will produce a heavy yield of nutritious forage. Fodder corn and millet are other crops that can be used for the same purpose. The land can be put back into grass again by sowing grass seeds after the pea harvest or in the corn at the last cultivation.

In Diagram XIII, numerous catch crops are shown that illustrate various methods of introducing catch crops into the rotation.

In Diagram XIV, given herewith, the rotation plan in Diagram XII is used to illustrate the use of catch crops for autumn pasture, under conditions where it is desired to make full and complete use of the resources of the farm for live stock production.

Diagram XIV. The Use of Catch Crops in the Rotation.

(Plan similar to Diagram XII, but with addition of the catch crops).

1. Corn—Catch crop of rape sown at last cultivation and pastured late autumn.
2. Oats—Mammoth clover sown in spring with oats and pastured early autumn.
3. Wheat—Grasses seeded this year with wheat.
4. Meadow—Catch crop of peas and oats or fodder corn in case grass crop is thin or entirely frozen out.
5. Pasture.

NOTE: In this rotation plan (same as Diagram XII) a large amount of supplementary pasture for live stock could be provided on the fields occupied each year by the corn and oat crops.

Rape seed could be scattered in the corn at its last cultivation and after corn harvest the rape crop would furnish a rich pasture for sheep or cattle in the late autumn. Rape is not injured by early autumn frosts and will furnish feed until late. As this corn land is not fall plowed but spring disked for the succeeding crop of oats, the land can be pastured until very late. Where hogs and cattle are being fattened in the autumn months a portion of this corn and rape crop can be temporarily fenced off, if desired, and stock turned in a few hours every day to feed off both the corn and the rape, thus reducing some of the labor expense of crop growing and live stock feeding.

Additional supplementary autumn pasture can be provided in this rotation by seeding mammoth clover with the oats in the spring of the year, and pasturing off the clover in the early autumn. Pasturing would have to cease on this field in time to permit fall plowing in preparation for wheat.

In this plan there is also an illustration of the use of catch crops to take the place of regular crops in the rotation that have failed to make a productive stand. In the event of the failure of a grass crop, fodder corn can be planted, and the fodder thus secured will take the place of the regular hay crop. When the fodder corn is cultivated for the last time, grass seeds may be scattered and covered with the cultivator, thus producing a stand of grass for the ensuing year. A mixture of peas and oats could also be sown, to produce forage in the event of grass failure. Winter rye could be sown after the pea harvest to provide spring and early summer pasture for the ensuing year, or, if desired, the land could be put back into grass by sowing grass seeds after the pea harvest.

Millet and fodder corn are two good catch crops that can be used to take the place of spring sown, annual crops, that sometimes fail on account of early summer drouth or hail. Unforeseen crop damage can thus be largely recovered, providing the farm is carrying sufficient live stock to utilize the forage.

The Use of Green Manure Crops in the Rotation. Green manure crops are grown for the particular purpose of adding vegetable matter to the soil. A heavy green manure crop offers the quickest possible method for restoring productivity to old, badly tilled, worn out soils in a poor physical and chemical condition, or for increasing the productivity of sandy soil.

The green manure crop is rarely used or needed on farms where pasture lands are rotated, where there are plentiful supplies of barnyard manure, or where annual, catch crop pastures are used to supplement the regular pasture land. Under these conditions a humus equilibrium is easily maintained in the soil and there is little need for the green manure crop. But where the permanent pasture is used instead of the rotation pasture, and where annual catch crop pastures are not in use, or where a long cycle rotation for grain farming is practiced, the green manure crop is a necessity in maintaining a humus equilibrium and keeping soils in a high state of productivity through long periods of time.

Green manure crops are introduced into the rotation in the same manner as catch crops that are sown with or between regular crops. The best crops to use for green manure purposes are crops belonging to the legume family, because such crops are associated with the bacteria which gather atmospheric nitrogen. Green manure crops can be introduced into rotations to the best advantage usually after the small grain crops. In that event the green manure crop should approach maturity before being plowed under. Legume crops, as they approach maturity, contain more stored up supplies of nitrogenous matter than when young and before seeds begin to form, and thus it is better to plow under the crop during the late than the early stages of growth. The best legume crops to be used for green manure pur-

poses are cowpeas, soy beans, field peas, vetches, and mammoth clover. The choice of these crops depends on the adaptability of the crop to the local climatic conditions, the length of the season in which the crop can grow, and the cost of the seed necessary to start the crop. All of these crops except mammoth clover would be sown after the grain crop had been removed from the land, and in a seed bed prepared by thorough disking or shallow plowing. The mammoth clover seed should be sown with the grain crop in the spring

Plowing under a green manure crop of Canadian field peas. Green manure legume crops are especially useful as a means for quickly restoring humus and nitrogen to worn lands, or to improve sandy lands, at the minimum of expense.

of the year and would grow a great mass of foliage after the grain crop had been removed.

Some reference has been made to the use of green manure crops in rotation plans in Diagrams X and XI and also the methods for introducing these crops into the rotation plan. The use of green manure crops in rotation plans on farms having permanent pastures is illustrated in Diagram XIX. Their use in long cycle rotations on grain growing farms is illustrated in the accompanying diagram, number XV. This is the same rotation plan as number XI, but reproduced here to illustrate the use of green manure crops in greater detail.

Diagram XV. The Use of Green Manure Crops in a Long Cycle Rotation on an Extensive Grain Growing Farm.

(Plan similar to Diagram XI, but with addition of green manure crops.)

1. Corn.
2. Wheat or Barley—Green manure crop plowed under in late autumn.
3. Wheat—Grasses seeded.
4. Meadow.
5. Pasture.
6. Wheat or Flax.
7. Oats—Green manure crop plowed under in late autumn.

NOTE: On land already in a high state of productivity this rotation would keep the land in good physical condition, and in a high state of productivity, for many years, without the use of green manure crops, especially if the two grass crops were fully used by live stock and the manure returned to the soil.

In instances, however, where an old grain growing farm has become badly run down, and the soil is in a poor physical condition and deficient in available plant food, it would be necessary to introduce green manure crops into the rotation to quickly bring the soil to a condition of high productivity. The green manure crops could be introduced into this rotation in two places to advantage: (1) after wheat or barley in the second year of the rotation; and(2) after oats in the seventh year of the rotation. Whether it would be advisable to use one or two green manure crops in this rotation would depend entirely on the physical condition and productivity of the soil. If the land is in a badly run down condition, it would be advisable to use green manure crops in both the second and seventh years of the

rotation until the land had been put in good condition again, when one of the green manure crops could be abandoned. The most logical place to introduce a green manure crop in this rotation would be with the oat crop in the seventh year, because of the fact that corn, a gross feeding crop, follows the green manure, and because a green manure crop in this place in the rotation is midway between the grain and cultivated crops that are on the land between those periods when the land is occupied by grass crops.

A heavy green manure crop in the second year of the rotation, following wheat or barley, would probably cause rank straw and lodged grain in the third year of the rotation, if the land were very rich and productive. On worn out land, however, this difficulty would not be encountered, and the green manure crop would be of distinct benefit in improving the physical condition of the soil and in releasing available plant food.

In the grain growing sections of the North Central states, to which this particular rotation is best adapted, the best green manure crop to use would probably be mammoth clover. Three or four pounds of seed per acre, sown with the grain in the spring of the year, would produce a heavy growth of foliage in the late summer and autumn, after the grain crop was removed from the land, and, when plowed under, would greatly enrich the land. One of the greatest advantages of using this crop for green manure purposes is that it requires no extra labor whatsoever to include the crop in the rotation. The seed is sown with the grain in the spring of the year, and there is no work to be done on the green manure crop after the grain harvest. The only cost of the crop is for seed, and this is a small item compared with the benefits to be gained. Other crops than mammoth clover can be used, however, if desired. Early maturing soy beans, field peas and vetches make good green manure crops. When these crops are used, the grain stubble land should be disked or shallow plowed after the grain harvest to destroy weeds and to prepare a seed bed in which the green manure crop can make a quick start.

When the green manure crop is plowed under in the late autumn, the work of plowing needs careful attention; for a poor job of plowing will leave a rough seed bed for the succeeding crop. The land should be plowed a little deeper than usual to bring up enough soil to thoroughly cover the vegetation, and the rolling coulter and a drag chain used to roll under the green manure crop in nice shape.

The Use of Cover Crops in the Rotation. Cover crops, sown for the particular purpose of preventing soil washing and the loss of soluble plant food during seasons when soil areas are not occupied by regular crops, are not extensively used in the Northern part of the Temperate Zone where the soil is frozen solid for five or six months in the year. In more

southerly regions, however, where there is a distinct winter season, but where the winters are comparatively mild, and where considerable soil washing takes place during the winter season, the cover crop is often used to check the process of soil washing and the loss of soluble plant food. The cover crop is especially useful in protecting soils after the growth of a cultivated crop where the bare soil and furrowed ground are very susceptible to soil washing.

Generally the cover crop used is one that will withstand the winter climate and start growth again in the spring of the year. It is usually sown with the cultivated crop in early autumn, allowed to stay on the land all autumn and winter, allowed to produce considerable foliage again in the early spring, and is then plowed under in preparation for the regular spring sown crop. In this manner the soil is covered with a mulch from the harvest season of one year until the seeding season of the following year, and little soluble plant food is washed away. The cover crop, during its growth, absorbs a large part of the soluble plant food of the soil, and when plowed under this soluble plant food is returned to the soil for the succeeding crop.

Crimson clover, sweet clover, and winter rye are very commonly used as cover crops. In Diagram XVI three plans are shown for the inclusion of cover crops in rotations. It may be noticed that in all these plans the soil is never left uncovered at any period of the rotation cycle.

Diagram XVI. The Use of Cover Crops in the Rotation.

Plan No. 1.

1. Corn—Sweet clover "cover crop" sown in corn at last cultivation.
2. Soy Beans—Autumn sown wheat.
3. Wheat—Seed down to grass.
4. Meadow.
5. Pasture.

Plan No. 2.

1. Tobacco—Autumn sown rye "cover crop."
2. Tobacco—Autumn sown wheat.
3. Wheat—Seed down to grass.
4. Meadow.
5. Pasture.

Plan 3.

1. Corn—Crimson clover "cover crop" sown in corn at last cultivation.
2. Corn—Autumn sown wheat.
3. Wheat—Seed down to grass.
4. Meadow.
5. Pasture.

The Use of Alfalfa in Crop Rotation. Alfalfa cannot be as easily rotated in short cycles with the grain and cultivated crops as red clover, alsike clover, or mixtures of these clovers with timothy and brome grass. The reasons are that alfalfa is a perennial crop; that it requires at least one year, and more commonly two years in Northern climates to get a good stand; and that the seed is so costly as to make it impractical to be continually breaking up alfalfa sods and re-seeding new fields. A field of alfalfa, once well started, should remain as permanent meadow for at least five or six years before it is broken.

Thus, when alfalfa occupies one field for many years and is relied on as the sole source of cured hay, the remaining fields of the farm must grow grain crops and cultivated crops for long periods of time, and, even though alfalfa be rotated over all fields of the farm, relatively long periods must elapse when grain and cultivated crops occupy the land with no intervening humus producing crops Diagram XVII illustrates this point, and also the point that, while alfalfa can be successfully rotated in long cycle rotations, it is more difficult to systematically rotate it with grain and cultivated crops in short cycles.

Diagram XVII. Alfalfa and Systematic Crop Rotation.

(1)	(2)	(3)	(4)	(5)
1. Wheat	1. Alfalfa	1. Alfalfa	1. Alfalfa	1. Alfalfa
2. Alfalfa	2. Alfalfa	2. Alfalfa	2. Alfalfa	2. Alfalfa
3. Alfalfa	3. Alfalfa	3. Alfalfa	3. Alfalfa	3. Corn
4. Alfalfa	4. Alfalfa	4. Alfalfa	4. Corn	4. Oats
5. Alfalfa	5. Alfalfa	5. Corn	5. Oats	5. Corn
6. Alfalfa	6. Corn	6. Oats	6. Corn	6. Wheat
7. Corn	7. Oats	7. Corn	7. Wheat	7. Alfalfa
8. Oats	8. Corn	8. Wheat	8. Alfalfa	8. Alfalfa
9. Corn	9. Wheat	9. Alfalfa	9. Alfalfa	9. Alfalfa

(6)	(7)	(8)	(9)
1. Alfalfa	1. Corn	1. Oats	1. Corn
2. Corn	2. Oats	2. Corn	2. Wheat
3. Oats	3. Corn	3. Wheat	3. Alfalfa
4. Corn	4. Wheat	4. Alfalfa	4. Alfalfa
5. Wheat	5. Alfalfa	5. Alfalfa	5. Alfalfa
6. Alfalfa	6. Alfalfa	6. Alfalfa	6. Alfalfa
7. Alfalfa	7. Alfalfa	7. Alfalfa	7. Alfalfa
8. Alfalfa	8. Alfalfa	8. Alfalfa	8. Corn
9. Alfalfa	9. Alfalfa	9. Corn	9. Oats

NOTE: In this plan sufficient grain producing crops have been included with the alfalfa to give a plan suitable for general grain and live stock farming. Each field of alfalfa remains unplowed for five years in order to keep the alfalfa seed cost at a minimum, and in order to allow time for the alfalfa crop to obtain its maximum productiveness. The rotation would occupy nine years in completing its cycle, alfalfa occupying the land for five years and grain producing crops for four years.

The rotation would be better balanced were a legume crop such as field peas introduced in the eighth year of the rotation, after corn, with oats the ninth year and corn the tenth year, thus making a ten-year rotation. If the rotation is planned as a nine-year rotation, a green manure crop could be introduced to advantage with the oat crop of the eighth year.

Such a rotation plan, with its preponderance of alfalfa, is suited only to regions where alfalfa is a certain and dependable crop, and where the feeding of live stock or the sale of alfalfa hay is practical and profitable. It is a plan ill suited to small farms, because it necessitates dividing the farm area into nine or ten fields, and should the total farm area be small, each field would be too small for the practical operation of machinery and for good field management. This

plan, or some plan of a similar nature, however, could be adopted on large farms of 640 acres or more in size, where it is desired to make alfalfa the main crop.

Alfalfa cannot be systematically rotated on small farms with corn and small grains in regions where it is desired to make corn, wheat, oats, or other small grains, the chief products of the farm. It must occupy the land for a relatively long period of time, and for this reason it becomes the chief crop of any farm where it is systematically rotated with the grain and cultivated crops. The clover grass crops are much better adapted for rotation with corn and the small grains, where these crops are staple crops, than alfalfa. In regions where alfalfa is a certain and dependable crop a system of agriculture which makes alfalfa the main crop is most profitable and advisable. Alfalfa is the most perfect animal food known to man; it is very productive and cheaply produced;

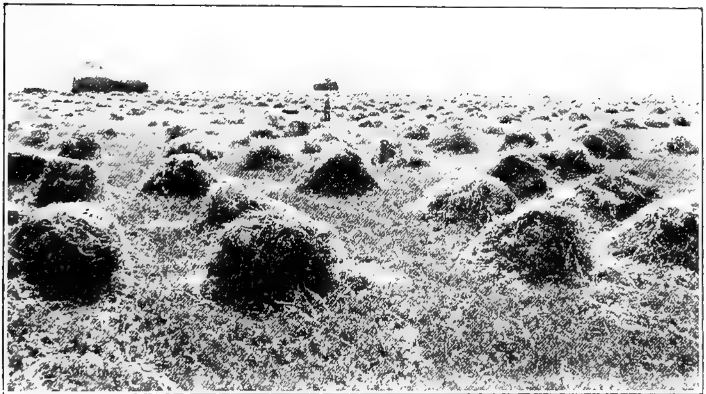


Photo by courtesy Montana Ranches Company.

Alfalfa is not so well suited to short course rotations with grain and cultivated crops as red clover. Whenever alfalfa becomes one of the main crops of the farm it should be left in permanent fields for five to ten years. Grain and cultivated crops will then be rotated over the other fields of the farm with annual pastures and green manures employed to maintain the humus and nitrogen supply of the soil.

and it can be rotated successfully with grain and cultivated crops under the conditions named in the notes accompanying Diagram XVII.

If alfalfa is to be grown in regions where it is not an absolutely certain crop, and where corn and small grains are staple, it is better policy to set aside for alfalfa an odd field that does not easily fit into a rotation plan with the other fields of the farm, than to try to rotate it with the main crops of the farm. Red clover, alsike clover, mammoth clover, and crimson clover, as meadow and pasture crops, as well as humus producing and nitrogen gathering crops, fit into a short cycle rotation with corn, wheat, oats, barley, cotton, potatoes or sugar beets, much better than alfalfa. Alfalfa is a distinctly valuable crop, however, on any live stock farm for its unsurpassed feeding qualities, and a few fields of this crop will yield a most valuable feeding adjunct to grain feeds such as corn and oats. Alfalfa is also an excellent crop to establish on the rolling portions of farms. It holds the soil from washing badly and provides the best of pastures.

One advantage that alfalfa has over red clover and alsike clover as a hay and pasture crop for live stock is, that its deep roots enable it to survive periods of drouth that are fatal to new seedings of the clover crops. This fact about alfalfa is worthy of consideration in some climates, as well as its productiveness and nutritive value. In Diagram XVIII, a plan is briefly outlined whereby alfalfa can be grown on farms where conditions necessitate a short cycle rotation and not disrupt a practical plan of crop rotation on all the fields. This plan would be specially adapted to live stock farming, and, with the large amounts of manure produced under such conditions, the soil would undoubtedly be kept in a high state of productivity.

Diagram XVIII. Alfalfa Field Combined with a Four-Year Rotation for Farm Conditions Necessitating a Short Cycle Rotation.

(1)	(2)	(3)	(4)	(5)
1. Alfalfa	1. Corn	1. Oats	1. Wheat	1. Clover
2. Alfalfa	2. Oats	2. Wheat	2. Clover	2. Corn
3. Alfalfa	3. Wheat	3. Clover	3. Corn	3. Oats
4. Alfalfa	4. Clover	4. Corn	4. Oats	4. Wheat
(Alfalfa land shifted to field 5)				
5. Corn	5. Wheat	5. Oats	5. Clover	5. Alfalfa
6. Oats	6. Clover	6. Wheat	6. Corn	6. Alfalfa
7. Wheat	7. Corn	7. Clover	7. Oats	7. Alfalfa
8. Clover	8. Oats	8. Corn	8. Wheat	8. Alfalfa (Indefinite)

NOTE: The plan of this rotation, designed to include alfalfa in a practical manner on small farms necessitating short cycle rotations, is, to seed down one field permanently to alfalfa for a period of several years and to carry out a four-year rotation including red clover on the remaining fields of the farm. When it is desired to break up the alfalfa field, a new seeding can be made with one of the grain crops, and if a successful stand is secured, the old field can be broken up and planted to some strong growing crop like corn. After the new field of alfalfa has become established, the four-year rotation proceeds on the remaining four fields as before. The only important difference in this plan from that of an ordinary four-year rotation is, that, in the year when it is desired to seed a new crop of alfalfa, grass seeding would have to be done on two fields, one field for alfalfa, and the other for red clover.

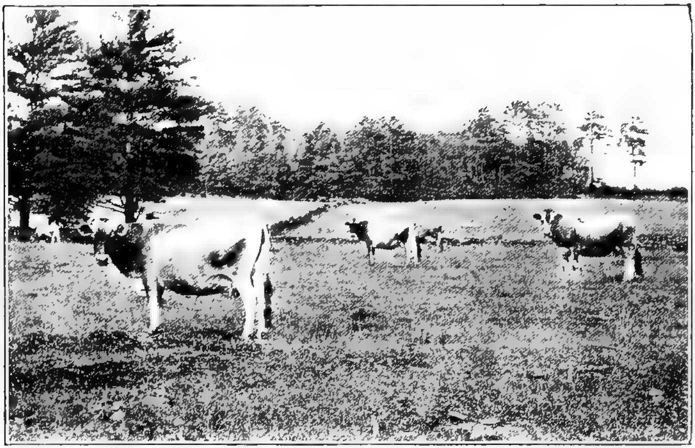
In making the shift of fields necessary to establish a new seeding of alfalfa it may be noticed that on field No. 2 a wheat crop is sown following a clover crop. Under most soil conditions it would probably be better to plant a cultivated crop, such as corn, on the clover sod. If the soil is light and not heavliy supplied with available nitrogen, this place in the rotation would be excellent for wheat. If the soil conditions are such that wheat would probably lodge, if sown on a clover sod, a crop of corn could be planted after the clover and a new seeding of clover made in the corn at its last cultivation, thus putting the land back into clover and its prescribed place in the four-year rotation.

If a plan of this kind, which produces a large amount of hay each year in proportion to the amount of grain, is impractical on account of this fact, it would be possible to substitute corn or oats for the clover, and to maintain a humus equilibrium on the fields of the four-year rotation by means of green manure crops. The red clover field could also be used for pasture, providing the land were not pastured too closely. By pasturing the hard alfalfa land early in the spring and

allowing the clover crop to make a strong start, it could be used for pasture during the summer months without any difficulty.

It should be understood that this plan is diagrammatic and shows only one of several plans that could be made to combine alfalfa fields with short cycle rotations.

Permanent Pastures and Crop Rotation. In the opening paragraphs of Chapter V it was stated that systematic crop rotation, with the use of rotation pastures, is impractical on some farms where there are rough lands, or fields cut up badly by streams, that will produce permanent pasture grasses, but cannot be included in a rotation plan with the arable lands of the farm. Many farms in the United States have lands of this kind which prevent reorganization of the farm by such methods as are shown in Diagrams II to VII, and where permanent pasture is the only revenue that can be derived from certian areas. Furthermore, in some regions the permanent pasture of white clover and blue grass is preferred to the rotation pasture of red clover and timothy,



A pasture scene in New England. The permanent pasture is a necessity on the majority of farms because of the stony soil and rough topography. The grass crop of these lands is utilized to the best advantage by dairy cattle.

or alsike clover with timothy or brome grass. The rotation pasture does not thicken up on the ground and stand as continuous and close pasturing and tramping by cattle and sheep as the firmly established white clover and blue grass pasture.

Where mixed grain and live stock farming is practiced and where it is not necessary to pasture land closely, the rotation pasture is usually to be preferred, wherever all areas of the farm are arable or can be made so. The rotation pasture distributes manure periodically over all areas of the farm without any costs, and keeps up the general productiveness of the farm lands at the least expense. Thus, when mixed grain and live stock farming is being practiced, the rotation pasture is preferable, wherever possible, in consideration of the effect it has on the productiveness of all crops in the rotation.

Where land is to be pastured closely by dairy cattle or sheep, and where live stock enterprises constitute the chief business of the farm, the thick sod of a white clover and blue grass permanent pasture is preferable to the rotation pasture, in some agricultural regions. In such a case there is more manure available on the farm to spread on the plow land than where mixed grain and live stock farming is being practiced. The use of this manure from large numbers of live stock will do much toward keeping up the productivity of the plow land on the farm, and then, if green manure crops be occasionly grown on the plow lands, the productivity of the fields can be kept up as well as though pasture lands were periodically rotated over the farm. If conditions indicate that the permanent pasture of white clover and blue grass will yield more pasture than the rotation pasture of red clover and timothy, the arable land used for permanent pasture can be left unbroken for relatively long periods of time, and the other crops of the farm rotated

with clover meadow and green manured occasionally in much the same manner as was shown in Diagram XVIII, illustrating the method of rotating farm crops where one field of the farm is kept permanently in alfalfa.

In Diagram XIX a rotation plan is shown that will illustrate a practical method for rotating crops on farms where the permanent pasture is a necessity, or where it is desirable to keep a portion of the arable land in permanent pasture for relatively long periods of time. This plan is not copied from any actual survey, but is merely a diagram to illustrate methods that can be applied to any farm where these conditions prevail.

Diagram XIX. Crop Rotation with Permanent Pasture Lands.

(1)	(2)	(3)	(4)	(5)
1. Pasture	1. Corn	1. Oats (Green manure)	1. Wheat	1. Meadow
2. Pasture	2. Oats (Green manure)	2. Wheat	2. Meadow	2. Corn
3. Pasture	3. Wheat	3. Meadow	3. Corn	3. Oats (Green manure)
4. Pasture	4. Meadow	4. Corn	4. Oats (Green manure)	4. Wheat
(Pasture land shifted to field 2)				
5. Corn	5. Pasture	5. Oats (Green manure)	5. Wheat	5. Meadow
6. Oats (Green manure)	6. Pasture	6. Wheat	6. Meadow	6. Corn
7. Wheat	7. Pasture	7. Meadow	7. Corn	7. Oats (Green manure)
8. Meadow	8. Pasture (Indefinite)	8. Corn	8. Oats (Green manure)	8. Wheat

NOTE: This diagram shows a farm divided into five fields, one of which is permanent blue grass and white clover pasture. On the other four fields of the farm, a four-year rotation of corn, oats, wheat and meadow is practiced. The meadow land is broken each year in preparation for the succeeding corn crop. A green manure crop is sown with the oats and plowed under late in the autumn.

If the permanent pasture land is rough and incapable of tillage, this land must, of course, stay in grass always, in which event the four-year rotation is practiced on the other four fields without any interruption. If the land in permanent pasture is arable, and growing permanent pasture only because it is the desire of the farm manager to do so, the pasture can be shifted at any time, every five to eight years, to any other field of the farm.

The upper half of this diagram illustrates the rotation of the crops in the event that the permanent pasture is rough, untillable land. The lower half of the diagram, taken in connection with the upper half, illustrates how the permanent pasture can be shifted from one field to another, in case all areas of the farm are arable. Suppose, for example, field 1 is arable, and has been in permanent pasture so long that the grass is sodbound and a change of pasture is deemed desirable. Two years prior to the shifting of the pasture the change must be planned for by mixing white clover and blue grass seeds in the regular grass mixture used for meadow grass seeding. Then, if a good stand of grasses is secured, the old pasture sod can be broken up for corn, and the meadow land goes into pasture. Meanwhile grass seeds have been sown with the wheat crop of the previous year, and thus, as soon as the old pasture sod is broken, new pasture land and new meadow land have been prepared, so that the new pasture land can remain permanent pasture indefinitely, and the four-year rotation continues over the balance of the farm as shown in the upper half of the diagram.

With one year of meadow and one year with a green manure crop in this four-year rotation, there is no question that the system of cropping will maintain soil productivity. This rotation is practically the same as the one shown in Diagrams VII and XII, and just as good in every respect. The permanent pasture need not stand in the way of successful crop rotation, if the meadow land is rotated over the arable fields of the farm, if deep rooted legumes like red clover or mammoth clover are used for the meadow crop, and if occasional green manure crops or catch crops for supplementary pasture are used to assist in maintaining a humus equilibrium in the soil.

Rotation Plans without Pasture Lands for Intensive Systems of Live Stock Farming. Where land values are very high, and farms located close to big cities where there is great demand for fresh dairy products, a system of dairy farming is sometimes adopted that does not provide pas-

ture for the cows, but soiling crops and ensilage for the summer green feed. Of course such a system of dairy farming is more expensive than one that provides the summer feed by means of pasture land. But the system permits a greater number of cows to be kept on a given area of land than when pasture lands are used for summer feed. Thus the gross income from a given area of land is materially increased, and while the costs of the business may be higher than in case a portion of the farm area is in pasture land,

Photo by courtesy "Hoard's Dairyman."

Specialized dairy farming on farms of 80 to 160 acres in size, without pastures, and with summer feed provided by means of silage and soiling crops, is one of the best solutions of the problem of securing a satisfactory profit from high priced agricultural land.

the costs do not increase in proportion to the increase in gross income, and, therefore, the net profit from a given area of land is greater.

If close to a big city, the relatively small, highly developed, dairy farm that keeps a large number of cows on a given area of land by means of summer soiling crops and ensilage, is a very profitable type of farming and successful so long as a sufficient labor supply is available to con-

duct the business. This method of farming, in fact, offers one of the best solutions to the problem of making the small, high priced farm pay a good dividend on the investment.

Rotation plans for this kind of farming can be made very simple. The productivity of the soil is easily maintained with the large amounts of manure available, and, therefore, the rotation can be planned with but one main object in veiw, namely, to produce the largest possible amounts of roughage and grain feed from the farm area for the feeding of the live stock, and at the same time to arrange the fields in a systematic manner. The plans must include ensilage crops for winter, spring and early summer feeding, and soiling crops that can be cut and fed green in the late summer and early autumn. Corn is the standard ensilage crop in most regions of the United States, with field peas, cowpeas, soy beans, or the clovers sometimes used to mix with the corn in the silo. The soiling crops most commonly used are corn, sorghum, and oats and peas mixed. The grain crops used in rotations of this nature should be those that produce seeds rich in proteids (nitrogenous matter), so that the feeder may have cheap proteid feed available to balance the food nutrients of the ensilage and soiling crops, and thus produce the food ration most desirable for milk production. Clover or alfalfa hay should also be grown on a farm of this kind in order to produce some roughage that is rich in proteid nutrients. Annual pastures of catch crops such as rape or clover can be used, if desired, in some plans to provide pasture for young cattle and dry cows.

In planning a rotation for a farm, where intensive dairy farming of this kind is to be practiced, the minor rotation close to the buildings would prove very useful, and should be used unless the farm area is small (80 acres or less). On

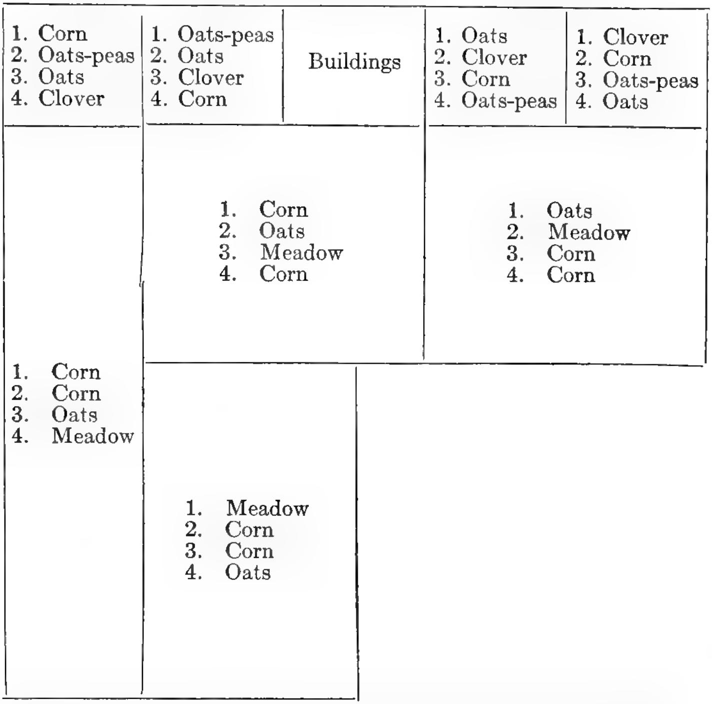
very small farms all fields are so close to the buildings that the minor rotation becomes impractical and unnecessary, but, on comparatively larger farms, the minor rotation fields are very useful in providing pasture for young stock and hogs, and for growing soiling crops close to the feed lots, so as to affect economies in the time involved in feeding the soiling crop.

Photo by courtesy "The Farmer."

Pigs pasturing in a field of oats and peas. Shoats grow fast on this feed during late summer and early autumn, and arrive at the final fattening period with good bone and muscle produced at small expense.

In the accompanying diagrams, Nos. XX, XXI and XXII, three rotation plans are shown that illustrate methods for growing crops on farms without pasture lands, and for practicing intensive dairy farming, or other specialized form of animal husbandry, on high priced farm lands.

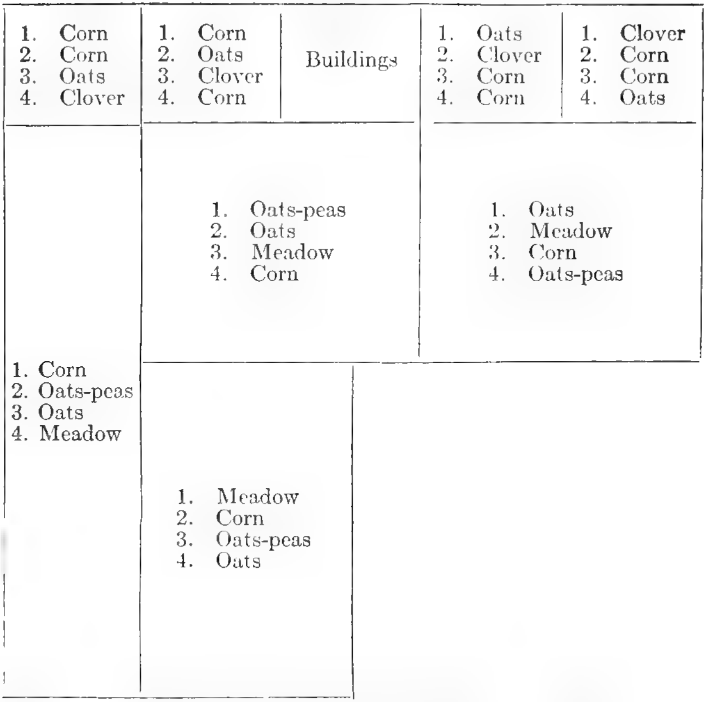
Diagram XX. Rotation Plan without Pasture Lands for a 120 Acre Farm.



NOTE: These Diagrams, Nos. XX and XXI, show a 120 acre farm, all arable, divided into four large fields of about twenty-five acres each, for the major rotation, and four small fields of about four acres each, for a minor rotation. The minor rotation fields, are fenced with hog fencing so that each field may be used periodically for hog pasture. The large fields are also fenced so that stock can be pastured on meadow aftermath, catch crop pastures, and on the stubble fields.

In Diagram XX the minor rotation consists of corn, oats and peas, oats, and clover. If desired, rape could be sown with the corn at its last cultivation to provide late autumn pasture for hogs and young stock. The corn crop can be used for summer soiling or allowed to mature and furnish feed in the field for fattening hogs. The oats and peas can be used for summer soiling or a portion of the crop

Diagram XXI. Rotation Plan without Pasture Lands for a 120 Acre Farm.



cured for winter forage. The oats are harvested and threshed. The clover crop, sown with the oats, furnishes pasture for brood sows, pigs and young stock.

In Diagram XX, the major rotation consists of corn, corn, oats and meadow. One crop of corn can be matured for grain, and the other used for summer soiling, ensilage and fodder corn. Rape, sown with this corn crop, would furnish autumn pasture. The oats would be harvested and threshed for grain feed. The clover meadow would be cut for hay and the aftermath pastured.

Diagram XXI is much the same as Diagram XX. The chief differences are that more corn is placed in the minor rotation to use for soiling and ensilage, and that a large field of peas and oats is included in the major rotation. This crop of oats and peas would furnish some summer soiling feed, but the main portion of the crop would

be allowed to mature to a point where pods were formed on the pea vines, and then the crop would be cut with a pea mower, cured in the field, and stored for winter forage. If desired, a portion of this pea and oat crop could be mixed with the corn silage and run into the silo. If desired, also, the pea and oat crop could be allowed to mature in the field, be cut and stacked, and the grain threshed out for feed. The oats in this rotation would be harvested and threshed for grain feed. The corn crop also would be matured for grain, except such portions as are needed to supplement the small fields of corn for ensilage and summer soiling. The clover meadow would be cut for hay and the aftermath pastured.

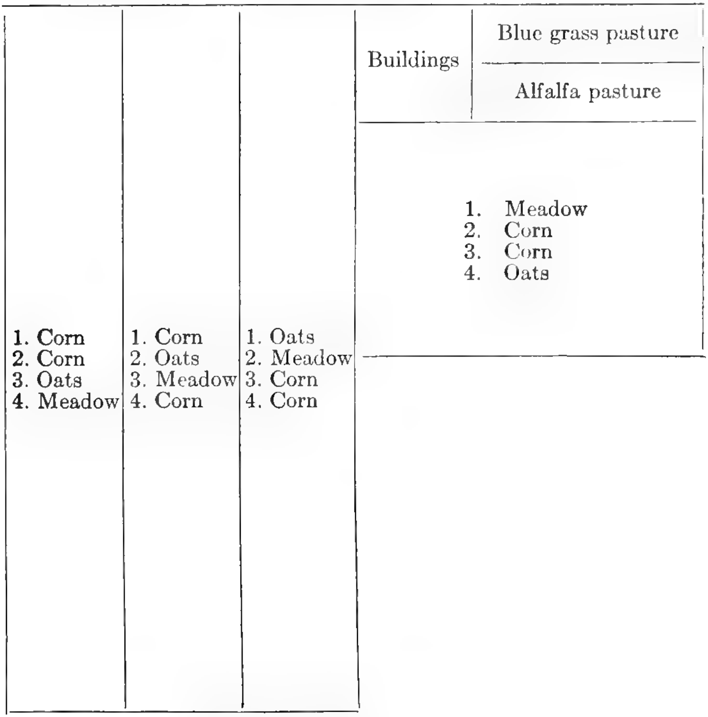
Wherever the oat and pea crop can be handled satisfactorily for either grain or cured feed, the rotation plan of Diagram XXI is somewhat preferable to the plan in Diagram XX, because a greater quantity of feed rich in protein is produced. The farm feeds produced in this rotation would make an almost perfect combination of foodstuffs for milk production. The feeder who had ensilage, clover hay, oats, and either pea grain or good pea hay, to draw on for feed supplies, would have a small bill for mill feeds.

With rotations such as these, which include heavy yielding soiling and ensilage crops, clover hay, grain, and catch crop pastures, the dairyman can stock land, if he so desires, to its maximum capacity, and with heavy milking dairy cows this kind of farming will return satisfactory profits on very high priced land.

Photo by courtesy "The Farmer."

'Hogging off" corn saves labor and expense in the fattening of hogs.

Diagram XXII. Rotation Plan Without Pasture Lands for a 120 Acre Farm.



NOTE: This rotation plan is mucn the same as the plans shown in Diagrams XX and XXI, with this difference: the minor rotation is eliminated and in its place two small fields of permanent blue grass and alfalfa pasture have been provided for hogs and calves. This permits a somewhat better arrangement of the large fields, and it also provides a plan requiring less labor.

This plan does not provide quite as intensive a system of farming as the plans in Diagram XX and XXI, but it effects some economies in labor and would, therefore, be preferable under certain farm conditions.

Under this plan, ensilage would be the chief dependence for summer feed. Annual catch crop and aftermath pastures could be used if desired. Crops would be handled by the same methods outlined in the note accompanying Diagrams XX and XXI.

PROBLEMS AND PRACTICUMS

(1) Which type of rotation, the short or long cycle, is best adapted to the majority of the farms in your community? Why?

(2) Which type of pasture is considered the most profitable in your community, the permanent or rotation pasture? Why?

(3) Using your local costs for posts, wire and labor, what is the cost per rod of fencing an 80 acre field 160 rods long and 80 rods wide, with 4 inch cedar posts set 20 feet apart and with 3 strands of barbed wire, and including 4 braced gate posts as well as 4 corner posts? What is the cost per rod with 4 inch cedar posts set 20 feet apart and with 35 inch woven wire and 1 strand of barbed wire? With steel posts 20 feet apart, 26 inch woven wire, and 2 strands of barbed wire? See page 479.

(4) How many acres of pasture are necessary, on the average, in your community to pasture a mature cow or a steer? What is the annual cost of an acre of pasture in your community? (Calculate current interest on land investment, together with taxes, annual proportion of seed cost, and annual fence cost.)

(5) What is the annual cost of an acre of pasture when land is worth $25.00, $50.00 $100.00, $150.00 and $200.00 per acre?

(6) If 40 acres of land, valued at $100.00 per acre, will pasture twenty 1,000 pound milk cows, averaging 20 lbs. of 4% milk daily for 160 days, what is the profit per acre of pasture from the sale of milk, when butter fat is worth 30 cents per pound?

(7) If dairy cows are summer fed on ensilage, corn, oats, and clover, on land valued at $100.00 per acre, is the net acre profit greater or less than when land is devoted to pasture for summer feed, assuming the flow of milk to be the same in either case? (To solve this problem the first step is to calculate a ration that will meet the requirements of the cows. See "Haecker Feeding Standards," page 473 of this book. Compute the ration for a 1,000 pound cow yielding 20 pounds of 4% milk daily. Determine the total amounts of silage, corn, oats, and clover, for feeding one cow 160 days—the pasture period. Determine the acres required to produce this amount of feed for one cow with average crop yields such as: silage 10 tons per acre; corn 50 bu. per acre; oats 40 bu. per acre; and clover 2½ tons per acre. Determine the cost of producing this amount of feed for one

cow—see page 490 of this book—and reduce this cost to the basis of one acre. Determine the number of cows that can be supported on 40 acres of land for 160 days, when fed this ration, by dividing the total acres [40] by the number of acres required to produce the necessary feed for one cow.)

With this data in hand the acre profit from pasture land and stall feeding in summer is easily computed. Calculate in each case the total amounts of butter fat produced for 160 days and the value of same; the cost of the pasture or the crops fed out; and the difference, when reduced to the net return per acre, will show the comparative acre profit.

This problem is intended merely to show approximate returns per acre over and above the cost of feed. The cost of milking and interest on the value of the cows would enter into the problem if an exact comparison were made.

(This problem is taken from Circular 5, Cost Accounting Section, Division of Farm Management, Minnesota Agricultural Experiment Station.)

(8) Draw a series of plans, covering the period of time necessary, that will illustrate the reorganization of an old farm and the establishment of systematic crop rotation. The basis of these plans should be the diagram of your home farm or other farm you are familiar with, as referred to in question (5), Part II, Chapter V. Carefully study the reorganization plans shown in Part II, Chapter V to note all facts that must be taken into consideration. In choosing the crops to be grown and in making the rotation plan, consider the personal preferences of the farm manager, the character of the soil, the climate, the topography of the land, and the markets.

These plans should be in detail and should show all steps necessary to establish the perfected scheme of cropping. Estimate the costs of the reorganization work, such as fencing or drainage. Estimate the total crop yields per year on the perfected plan, at average yields per acre, and show plans for the disposal of the crops. Estimate the number of dairy cows, fat cattle, young cattle, swine, or sheep that the plan will support or that it is your plan to feed on the farm. State what crops are to be "cash crops." In fact, project a concise plan of farm management on the basis of your perfected plan of cropping.

(9) What is the best type of plow to use in plowing under a heavy green manure crop? Give reasons.

(10) Study the adjustment of a plow to secure best results when plowing under a green manure crop. Study the work of various kinds of coulters, the jointer and the drag chain. Learn to adjust the depth and width of cut so as to cover the crop perfectly.

From Bulletin 125 Minn. Agr. Expt. Sta.

Clover and timothy sod. Backset after a crop of flax. Note the amount of vegetable matter left to the soil from the roots and stubble.

CHAPTER VII

ROTATIONS FOR NORTH CENTRAL STATES

General Statements about the Agriculture of the North Central States. The North Central states of the United States comprise Ohio, Indiana, Illinois, Michigan, Wisconsin, Minnesota, Iowa, Missouri, North Dakota, South Dakota, Nebraska and Kansas. This group of states is sometimes called the "Upper Mississippi Valley Region." With the exception of the Western portions of North Dakota, South Dakota, Kansas and Nebraska, these states are all within the humid climate zone, where rainfall is usually abundant for temperate zone plant life, and where the natural vegetation on the prairies was the luxuriant growing forms of the prairie grasses.

These states comprise the largest area of contiguous, productive plow lands in the United States. The greater part of the North American prairie, excepting the Canadian prairies, is within their boundaries. From these states comes the greater part of the corn, wheat, oats, barley, flax, and potato crops, as well as the bulk of the live stock products of the United States. The so-called "corn belt" of the United States is mainly within the boundaries of the North Central states. In fact, corn is the principal crop of Ohio, Indiana, Illinois, Iowa, Missouri, Nebraska and Kansas, and is grown extensively in all the other states in this region. Wheat is the other great staple crop of this region, being grown most extensively in North Dakota, South Dakota, Minnesota, Nebraska and Kansas. Wisconsin, Minnesota, and Illinois are famous dairy states, and in all the states the dairy industry, with the grass and forage crops that accompany it, is on

the increase. Cattle and swine feeding, accompanied by intensive farming methods, is also one of the great agricultural industries. While these crops and industries are the chief agricultural enterprises of the North Central states, there are many other crops grown that produce large values in agricultural wealth. Potatoes, tobacco, sugar beets, alfalfa, clover and the various grass crops, beans, peas, buckwheat, and small grains other than wheat, are grown in large quantities.

Crop rotation is eminently adapted to this region of the United States. There is a great variety of crops to choose from in planning the rotations, and, furthermore, for a great majority of the farms, the mixed grain and live stock system of farming is the system best adapted to the soil, the climate, the markets, and the farm labor conditions. There are, of course, some conditions where truck farming, intensive dairy farming, extensive grain growing, cattle grazing, or other form of specialized agriculture, are more attractive to the farm manager than mixed grain and live stock farming, but the mixed type of farming is now, and probably always will be, the most popular system of farming.

For these reasons the planning of crop rotations that will alternate the grain, grass, and cultivated crops, is comparatively easy in the North Central states. Moreover, in the greater part of this region the fertility of the soil has not yet been reduced to such a low level by continuous, one crop farming as to make the extensive use of commercial fertilizers a necessity, as is the case in other parts of the United States. Systematic crop rotation, the use of green manures and live stock, with thorough tillage, will keep this agricultural region productive for many years to come, if followed before wasteful methods of soil cultivation have proceeded as far as in some of the Atlantic Seaboard states. Crop rotation is

needed on a majority of these farms to provide present and future productive soil conditions and to systematize the field work.

The planning of crop rotations for the unirrigated lands in the semi-arid portions of Western Kansas, Nebraska, North Dakota, and South Dakota is a far more difficult problem than for regions having more abundant rainfall. In these regions the conservation of moisture is the chief problem. Deep plowing, thorough harrowing, sub-surface packing, and bare fallowing are the factors of crop production that must be chiefly considered. Controlling the moisture supply is the important agricultural problem. Grass crops are not as commonly grown as in the more humid sections of the North Central states. In many places brome grass is the only drouth resistant perennial grass that it is practical to

Photo by courtesy "Farmer and Breeder."

Cutting corn for the silo, or for separation into grain and fodder by the "corn husker and shredder." A common scene in the "corn belt" of the North Central states.

seed, and it is difficult to secure profitable stands of clover, alfalfa, or other legume crops. Progress is being made in discovering and breeding varieties of alfalfa and vetches that are hardy and productive in these regions of scant rainfall, but, nevertheless, the problem of growing productive grass crops in these regions is difficult.

Practical and profitable agriculture in these regions is chiefly confined to the growing of fall sown grain crops, spring sown grain crops on deep, fall plowed land, or such cultivated crops as the drouth resisting sorghums and Kafir corn. The most successful crops are quick growing annuals that can make their start on the stored up rain and snow water in the plowing, mature their seeds from the moisture that usually falls in spring and early summer, and ripen off before the dry, hot seasons of midsummer and late summer. Pastures and meadows, not irrigated, will usually dry up in midsummer in these regions, and are, therefore, relatively unprofitable crops.

For these reasons the problem of maintaining a humus equilibrium in the soils is indeed difficult. The natural supply of humus in those soils is small, and the bare fallows, cultivated crops, and grain crops soon exhaust it. The future will surely bring difficult soil fertility problems to these regions. At the present time these regions have not been cropped for many years, and the soils usually contain abundant supplies of available fertility. If enough moisture can be conserved for crop growth, the crops are good. But, with decreasing humus supplies, these soils will eventually become unproductive; for humus is the key that unlocks the plant food of the soil.

Wherever the header can be used to harvest grain, instead of the binder, in these regions, the humus equilibrium can be maintained quite well by plowing under the straw portion

of the crop. The difficulty with this practice is that the straw, when plowed under, lies between the furrow-slice and the subsoil and may cause the seed bed to dry out, because the seed bed is somewhat disconnected from the moisture of the subsoil. This difficulty, however, can be overcome by fall plowing, and, if necessary, by the use of a sub-surface packer or disk harrow with the disks set straight ahead, that is run over the land in the early spring. Green manure fallow can also be used in the place of bare fallow, and thus add occasional supplies of humus to the soil. Some of the hardy vetches are useful for this purpose. Brome grass sods are also a source of humus supply for the soils of these regions, but the amount of humus that can be turned under is comparatively small. Hardy varieties of alfalfa will doubtlessly be developed sometime that will prove adapted to many areas where alfalfa is now an uncertain crop.

Rotations for Small Grain Farming. Rotation plans for small grain farming have been quite thoroughly presented in Diagrams XI and XII and in the notes accompanying these diagrams. These plans are especially well adapted to those regions where the grain is all spring sown. They are also easily adapted to regions where wheat is autumn sown and where it is desired to make grain production the chief enterprise of the farm. The rotation plan in Diagram XI, for example, could be modified easily for winter wheat production by planning to seed winter wheat in the corn of the first year of the rotation, seeding oats after the pasture in the sixth year, and in the autumn of the sixth year seeding winter wheat for the seventh year.

A good short cycle rotation for the winter wheat regions of the North Central states is:

1—Corn (cover crop of soy beans).

2—Oats (fall sown wheat).

3—Wheat (seed down to clover).

4—Clover meadow.

This rotation is really better for mixed grain and live stock farming than for grain growing, as only one half the farm area is annually in grain; whereas, a long cycle rotation would provide a greater proportionate acreage of grain.

In the southern part of the North Central states, where the most productive varieties of soy beans will mature, a good four-year rotation for grain growing farms is:

1—Corn (fall sown wheat).

2—Wheat (fall sown wheat).

3—Wheat (green manure of clover or soy beans).

4—Soy beans.

All the crops of this rotation could be used as "money crops," if desired, and the green manure and soy beans would maintain the humus equilibrium and the available nitrogen

Photo by courtesy "Breeders' Gazette."

Soy beans grown for hay in Indiana. Yield 2½ tons of cured forage per acre. The soy bean is a legume, or crop which gathers atmospheric nitrogen by means of the bacteria that attach themselves to its roots.

supply of the soil. In regions where soy beans are not profitable as a seed crop, Canadian field peas could be substituted for the soy beans.

In the Northern timbered areas of the North Central states, where corn is not always a dependable seed crop, but where winter rye, oats and buckwheat are the commonly used, dependable crops, the following rotation is useful:

1—Buckwheat (winter rye).

2—Rye (seed down to clover).

3—Clover meadow.

4—Oats (green manure catch crop with oats).

Rotations for Corn Farming. Where it is desired to produce the maximum amount of corn from the farm area, the rotation plan should have as high a proportionate acreage of corn and as low a proportionate acreage of grain and grass crops as possible, and yet permit the principles of crop rotation. If the farm area is large, the long cycle rotation, such as the one outlined in Diagram XI, can be used, with corn predominating in the rotation instead of the small grains. If a corn growing rotation plan is made along the lines of Diagram XI, it should be remembered that, when many cultivated crops are introduced into the rotation, the decay and oxidation of humus will be comparatively rapid, and, therefore, occasional green manure or cover crops should be used to maintain the humus equilibrium.

A long cycle, seven-year rotation plan is given herewith to illustrate how corn production can be made to predominate in the rotation and yet the rotation be such as to correspond to the principles of crop rotation:

1—Corn (soy bean cover crop).

2—Corn on spring plowing (green manure crop fall plowed).

3—Corn.

4—Oats on disked corn land (seed down to clover and timothy).

5—Meadow.

6—Pasture (broken up in autumn).

7—Corn (rape catch crop for autumn pasture, fall plowed).

It may readily be seen how much better a system of cropping for corn production this plan is, as compared with the old system of permanent pasture with corn and oats alternated on the land not in grass, which made no provisions for the maintenance of humus and nitrogen.

On farms not adapted to the long cycle rotation the following plan is practical for corn production:

1—Corn (green manure crop fall plowed).

2—Corn.

3—Oats on disked corn land (seed down to clover).

4—Clover meadow, broken up in autumn.

Rotation Plans for Potato or Sugar Beet Farming. In Diagram X a short cycle, four-year rotation plan is shown, that illustrates the best methods for rotating crops in order to make root crops the chief product of the farm. Another good rotation giving special consideration to roots is:

1—Potatoes or beets.

2—Oats or wheat (seed down to clover).

3—Clover meadow, first crop hay, second crop plowed under.

The root crops can be introduced into rotations for mixed farming as follows:

1—Corn.

2—Oats on disked corn land (green manure crop fall plowed).

3—Potatoes or beets.

4—Wheat on disked potato land (seed down to clover)

5—Clover meadow, fall plowed.

Rotation Plans for Mixed Grain and Live Stock Farms. Rotation plans for this type of farming are shown in Diagrams XII and XIX that cover this subject quite thoroughly. This type of farming is usually followed in the North Central states on farms of 160 acres to 320 acres in size, and the practical rotation is, therefore, a four, five or six-year rotation so planned as to provide an excess of grain or corn over what is necessary for the live stock enterprises. In fact the standard type of rotation is the five-year rotation:

1—Corn.
2—Oats.
3—Wheat (seed down to grasses).
4—Meadow.
5—Pasture.

This plan can be easily modified according to the desires of the farm manager. Where it is desired to make corn the chief money crop or the chief grain crop for stock food, two crops of corn can be grown in the rotation instead of two crops of small grain and one crop of corn, or, where it is desired to make small grains the chief money crops, the rotation is planned as in Diagram XII. Where permanent pasture is included in the farm area the plan shown in Diagram XIX is well adapted for mixed grain and live stock farming.

Other rotations for mixed grain and live stock farming in the North Central states are:

(a) 1—Corn; 2—Soy beans; 3—Wheat (seed down to clover); 4—Clover meadow, fall plowed.

(b) 1—Barley; 2—Field peas; 3—Wheat (seed down to clover); 4—Clover meadow, fall plowed.

Rotation Plans for Tobacco Farming. Rotation plans to include tobacco should be modeled after the rotation plans where potatoes or sugar beets are the chief crop to be consid-

ered in the rotation. Tobacco is classed as a cultivated crop in planning the rotation, the same as corn, potatoes or sugar beets.

On relatively small, intensively managed farms, the short cycle rotation is best adapted to include tobacco and to provide a practical rotation. Two short cycle rotation plans that include tobacco are given herewith:

(a) 1—Tobacco; 2—Wheat (seed down to clover); 3—Clover meadow, first crop, hay; second crop plowed under.

(b) 1—Tobacco (clover or rye cover crop); 2—Tobacco; 3—Wheat (seed down to clover); 4—Clover meadow, first crop, hay; second crop plowed.

On relatively large farms in the North Central states, practicing mixed grain and live stock farming, tobacco can be

Photo by courtesy "Breeders' Gazette."

Cutting soy beans with the binder and following with the wheat drill. Rotation of corn, soy beans, wheat and clover—a very practical rotation for the southern part of the North Central states. The soy beans fit the land well for wheat.

introduced into the standard rotation along with other cultivated crops. If it is desired to grow a small field of tobacco each year as a money crop, this crop can be planted on a portion of that field in the rotation annually planned for corn, potatoes, or other cultivated crop.

Rotation Plans for the Western, Semi-arid Areas of the North Central States. Wherever irrigation is practiced in the semi-arid portions of Kansas, Nebraska, South Dakota and North Dakota, rotations can, of course, be practiced that will include all the staple grain and forage crops of the Northern part of the Temperate Zone, such as corn, wheat, oats, potatoes, sugar beets, alfalfa, red clover, alsike clover and timothy, according to the rotation plans previously described for the North Central states.

Many areas in the Western, semi-arid regions of these states, however, can never be put under ditch, and such agriculture as is practiced must depend on the natural rainfall for moisture for crop growth. In many large areas of these regions the annual rainfall is sufficient for good crop growth, but hot winds and drouthy periods in midsummer cause rapid evaporation of soil moisture and destroy the growth of the common field crops of the North Temperate Zone. In recent times the United States Department of Agriculture has introduced a number of drouth resistant crops from Asia and Africa that are more drouth resistant than the common grain and forage crops of North America, and these crops are proving to be of great aid to successful agriculture in these semi-arid regions.

The crops best adapted to these regions of scant rainfall and occasional summer drouths are herewith enumerated:

(1) **Grain Crops.** Durum wheat, awnless barley, sixty-day or Kherson oats, winter rye, emmer—sometimes called speltz, proso millet, Kafir corn, and durra.

2) **Forage Crops.** Proso millet—sometimes called hog millet, common millet, Kafir corn, durra, field peas, sweet clover, Dakota vetch, brome grass, Sudan grass and dry land varieties of alfalfa.

(3) **Cultivated Crops.** Durra, Kafir corn, proso millet, and Indian corn in some places.

(4) **Green manure Crops.** Dakota vetch, sweet clover, field peas, common millet.

All of these crops are annuals with the exception of brome grass and alfalfa, which are perennials, and sweet clover, which is a biennial.

When these crops are grown in these regions, and when deep plowing, thorough surface tillage, and occasional fallowing are practiced, good crops and profitable agriculture usually result. The grain crops, durum wheat, awnless barley, and emmer, are very much more resistant to drouth and hot winds than the bluestem and fife spring wheats and the malting barleys. The sixty-day, or Kherson oat, when sown early, makes its growth before the drouthy period of summer and thus avoids loss from drouth and hot winds. Similarly, winter rye starts early and matures before the period of crop danger. The durra and Kafir corn crops, introduced from Asia and Africa, have the power to resist a great amount of heat and drouth. They take the full growing season to mature, but, if the midsummer season is hot and dry, they have the power to remain dormant in growth and to start growth again with the coming of rain and cooler temperatures. Proso millet is also very drouth resistant and is an excellent substitute for corn in regions where corn is not a safe crop. The grain of either durra or proso millet is a nutritious stock food, and the yields are nearly as large as with corn—in fact, in semi-arid regions the yields are larger. These crops are also excellent forage

crops, if cut at the proper stage of maturity and properly cured. The proso millets, durra and Kafir corn, when grown for their seed value, are drilled or listed in rows 36 inches to 42 inches apart and inter-tilled during the summer months. Summer inter-tillage is usually beneficial in conserving moisture, and, for that reason, as well as the fact that these crops are naturally drouth resistant, they are exceptionally well adapted to many parts of the Western, semi-arid regions of the North Central states.

The use of catch crops and green manure crops, included in rotations by the methods shown in rotation plans for the humid areas of the North Central states, is usually impractical in these semi-arid regions. In most instances

Photo by courtesy W. A. Carleton, U. S. Dept. of Agriculture.

Blackhull Kafir corn, a valuable grain and forage crop for dry land agriculture as far north as the northern line of Kansas. It requires 115-140 days to mature and yields from 25 to 75 bushels per acre of grain. It withstands drouth and hot winds much better than corn.

there is not sufficient moisture to support more than one crop in a season. In fact, bare fallow is often practiced in these regions for the particular purpose of storing up an extra season's rainfall in the subsoil for the use of crops. Under these conditions green manuring, if practiced, must be done in the same manner as bare fallowing. That is to say, instead of including the green manure crop as a catch crop with the staple market crops, it must be sown and plowed under in a year when no other crop occupies the land. This can be done usually without difficulty and the crop gains in succeeding years will more than offset the costs for seed and tillage. In fact, the cost, in most instances, should be reckoned by a comparison with bare fallow, and thus the cost is merely a matter of seed and the labor of seeding.

When green manure crops are thus introduced in the rotation it should be planned to fall plow in preparation for the green manure crop, and to sow the crop at the first opportunity in the spring. Sixty to seventy days from the time of seeding the crop can be plowed under during the latter part of June when the soil is moist enough for good plowing. Then, during the remainder of the season, the green manured field should be occasionally harrowed and treated the same as a bare fallow. Autumn rains falling on such land will readily sink into the subsoil, and the land will be in fine shape for the succeeding grain or forage crop. Canadian field peas, Dakota vetch and sweet clover are the best legume crops available for green manure crops handled in this manner. These crops start quickly from seed and make a rapid, luxuriant growth on a moderate amount of moisture. A thickly sown crop of common millet, early sown, and plowed under while green, is also a good green manure crop in these regions, although not as desirable as

a nitrogen gathering legume crop. Sweet clover, which is biennial in habit, and hardy in Northern temperate zone winters, can be sown in the fall for green manure purposes, if desired. The seed can be sown among cultivated crops in the early autumn and covered with a cultivator, or, if the cultivated crop has been removed from the land, the seed can be disked or harrowed in. With a moderate amount of fall rain the sweet clover will establish itself and make a heavy growth the succeeding spring. It can then be plowed under in early summer to enrich the land, the land being left fallow for the balance of the season as in case of the spring sown green manure crops.

With the exception of brome grass and sweet clover there are no truly reliable meadow and pasture crops for this region of the North Central states, and even these generally become very short in midsummer. In many cases the stockman in these regions must supplement the native range or the brome grass or sweet clover pasture with such forage crops as millet, Sudan grass, Kafir corn, vetches, sweet clover, and field peas, and must depend on these forage crops for winter feed instead of the red clover, alsike clover, alfalfa, and timothy of the regions having greater rainfall.

Alfalfa is a dependable forage crop in some of these regions where the annual rainfall is sufficient for good crop growth, but where hot winds and summer drouth are ruinous to the ordinary forage crop. The alfalfa plant roots so deeply that, if once the crop is well established, it will withstand a great amount of summer drouth. Wherever climatic conditions will permit the growth of alfalfa, it is preeminently the best meadow and pasture crop, and rotations with grain and cultivated crops can be made according to the plans of Diagram XVIII, using durum wheat, emmer,

sixty day oats or winter rye for the grain crops, and Kafir corn, proso millet or durra for the cultivated crops.

Sweet clover demands attention as a practical and profitable forage and pasture crop in these semi-arid regions of the North Central states. It catches easily, grows quickly, is very resistant to drouth and cold and its powerful taproots will penetrate the hardest of subsoils. Moreover, under very adverse conditions it produces abundant crops of hay and pasture. The hay crop must be cut very early, as the natural habit of the plant is to rapidly grow woody and tough after blossoming. If cut early, however, the forage is of excellent quality, has very little waste, and is very nearly as nutritious as alfalfa. As a pasture crop it is unexcelled in semi-arid regions; for it starts early, grows late in the autumn, withstands summer drouth, and will stand very close pasturing. It is also a wonderful seed crop, and will produce from four to twelve bushels of seed per acre. Its only drawback is, that sometimes it is not palatable to stock that are accustomed to timothy, alfalfa, clover, or other forage crops, and stock have to be starved to it. Starving is not always necessary, but, when it occurs, it discourages the use of the crop and gives it a bad name. In spite of all drawbacks, however, the crop is being extended rapidly in the semi-arid regions of the United States as a forage, pasture and green manure crop. It is a biennial crop and is introduced into rotations in the same manner as clover and timothy. Several methods of seeding can be employed. The seed can be sown with a nurse crop of grain in the spring; it can be sown in cultivated crops in the early autumn or after early maturing cultivated crops have come off the land in the autumn; or it can be sown in the spring without a nurse crop,—the choice depending on local conditions of climate and other crops included in the rotation.

In the following paragraphs a number of rotations are suggested for grain farming and mixed grain and stock farming in these regions, that will alternate the crops best adapted to this region in a practical manner as regards moisture conservation, and also make some provision for maintaining a humus equilibrium in the soil. In these rotation plans the term "grain" is used to designate such crops as durum wheat, winter rye or wheat, emmer, awnless barley, or sixty day oats, the selection of these various grain crops to depend on local conditions and the desires of the farm manager. The term "green manure fallow," as used in these rotation plans, refers to such crops as Dakota vetch, Canadian field peas, sweet clover, common millet, or Hungarian millet, plowed under in early summer and the land fallowed for the balance of the season. The term "cultivated crop," as used in these rotation plans, refers to such crops as Indian corn, Kafir corn, durra, and proso millet, the choice depending on local conditions and the desires of the farm manager.

Grain Farming Rotations.

(a) 1—Grain; 2—Grain; 3—Green manure fallow; 4—Grain; 5—Cultivated crop.

(b) 1—Grain; 2—Green manure fallow; 3—Grain; 4—Grain.

(c) 1—Cultivated crop; 2—Grain; 3—Green manure fallow; 4—Grain; 5—Grain; 6—Green manure fallow; 7—Grain.

(d) 1—Cultivated crop; 2—Grain; 3—Green manure fallow; 4—Grain; 5—Green manure fallow.

(e) 1—Cultivated crop; 2—Grain; 3—Green manure fallow.

Mixed Grain and Live Stock Rotations.

(a) 1—Grain; 2—Brome grass; 3—Brome grass; 4—Cultivated crop; 5—Green manure fallow; 6—Grain.

(b) 1—Cultivated crop; 2—Grain; 3—Green manure fallow; 4—Grain; 5—Pea or vetch hay.

(c) 1—Cultivated crop; 2—Grain; 3—Pea or vetch hay; 4—Millet or Sudan grass hay; 5—Grain; 6—Green manure fallow.

(d) Same plan as Diagram XVIII, with one field in permanent alfalfa, and a four year rotation on the balance of the land—the four year rotation as follows: 1—Cultivated crop; 2—Green manure fallow; 3—Grain; 4—Cultivated crop.

(e) 1—Grain; 2—Sweet clover; 3—Cultivated crop.

(f) 1—Grain; 2—Sweet clover; 3—Cultivated crop; 4—Grain.

PROBLEMS AND PRACTICUMS

(1) What was the total production of corn in the United States in 1890, 1900, 1910? Name the states in the United States where corn production increased markedly during the periods above mentioned. What are the principal reasons for the extension of the American corn belt during these periods of time? See U. S. Census Reports.

(2) What are the most important "cash crops" of the North Central states?

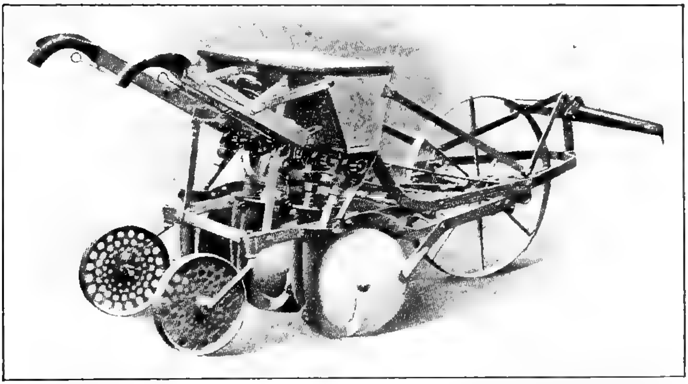
(3) Prepare a table from the United States Census Reports that will show, in the order of their importance, the values produced by the various agricultural enterprises of the North Central states. What are some of the specialized, intensive types of agriculture pursued in the North Central states?

(4) What is the average size of the farms in the North Central states? What per cent of the farm land area in these states is under cultivation? See U. S. Census Reports.

(5) Are there any large areas of virgin land remaining in the North Central states? If so, where located? What crops and types of farming are best adapted to these new regions? See reports and bulletins U. S. Departments Interior and Agriculture.

(6) Prepare diagrams and rotation plans for a fat cattle and grain farm; dairy, swine and potato farm; sheep and grain farm; intensive dairy farm; specialized grain farm; specialized potato farm; and a specialized corn and swine farm; for the North Central states. Elaborate the rotations fully on the diagrams. Show plans for disposal of the crops, and estimate the numbers of live stock that can be supported with average crop yields.

(7) Work out a rotation plan and a scheme of farming adapted to the upbuilding of sandy soil.



Courtesy of Beaver Dam Mfg. Co.

One-horse, five-disk, grain drill, by means of which winter wheat can be sown early between rows of standing corn.

CHAPTER VIII

ROTATIONS FOR NORTH ATLANTIC STATES

General Statements about the Agriculture of the North Atlantic States. The North Atlantic states comprise Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey and Pennsylvania. This group of states, in a general way, is often called "The New England States."

It was in the settlements and colonies of these states along the Atlantic Seaboard that North American agriculture had its beginning. Prior to the settlement of the Middle Western states the agriculture of the North Atlantic states was quite varied. All of the staple temperate zone crops were grown in considerable quantity, and the seaboard cities drew practically all their food supplies from adjacent lands. But, with the settlement of the Western prairies, a change took place in the agriculture of the North Atlantic states. Wheat, flax, barley, oats and corn could be produced cheaper on the rich, virgin prairies of the Middle West than on the small fields of the New England valleys. The grain grower of the North Atlantic states could not easily compete with the grain grower on the Western prairie. And so agriculture suffered a change. To a large extent grain growing and live stock fattening were abandoned and dairying, tobacco growing, potato growing, truck farming, and poultry farming, came to be the chief agricultural enterprises of these states. The breeding of pure-bred live stock for breeding purposes also came to be a prominent feature of agriculture, when the Middle Western states began to monopolize

the grain, corn, and fat stock production enterprises of American agriculture.

These changes in the character of agriculture, caused by the development of the prairie lands of the Middle West, have been further accentuated by the development of manufacturing and shipping industries. The growth of great city populations in these states, dependent on manufacturing for their support, has created an enormous demand for the perishable classes of agricultural products, such as milk, poultry, eggs, potatoes, fruits, and garden truck. Present day North Atlantic agriculture is mainly of a type to fill these demands for the perishable food products of agriculture used by city populations. In this type of agriculture the farmer has an advantage over his competitors in the Middle West; for the largest of all the American city markets is right at his door, and he has the advantage of a comparatively low freight rate into this market.

While wheat, rye, oats, barley and corn, are still grown to some extent in the North Atlantic states, they are most

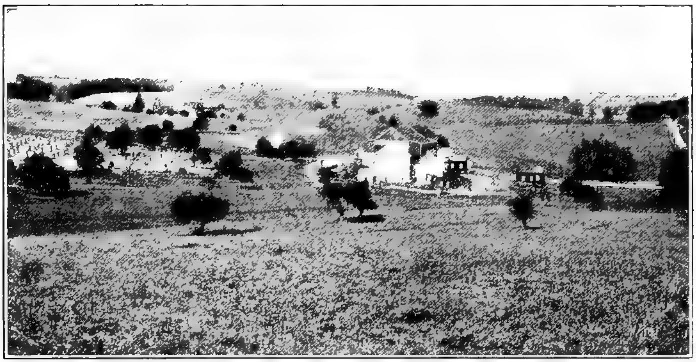


Photo by courtesy Pennsylvania State College.
A typical farm scene in the rolling hill lands of Pennsylvania.

commonly grown in connection with dairying, poultry farming and live stock breeding farms, rather than for market crops. As a matter of fact, there is not enough grain and corn produced in these states to supply the needs of the dairy industry and other live stock industries, and large amounts of oats, barley, corn and mill feeds are imported from the Middle Western states.

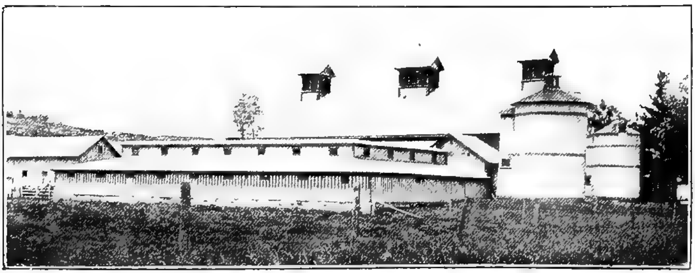
Dairy farming is the most common type of agriculture in the North Atlantic states. While it is almost universally practiced, it perhaps attains the highest development in New York. Wheat is still produced for market in some quantity in New York. Maine and New York are large producers of potatoes. Connecticut is famous for its tobacco, and tobacco is also a staple crop in portions of Pennsylvania. New Jersey is famous for its sweet potatoes and its truck farms. These are the chief crops and agricultural enterprises of this group of states. Many of these states are large producers of tree and vine crops also, but such crops and industries do not enter into a discussion of field management and crop rotation.

The meadow and pasture crops of the North Atlantic states are those that are common to all the Northern part of the Temperate Zone. Red clover, alsike clover, mammoth clover, white clover, timothy, redtop, blue grass and alfalfa, are the grass crops most widely cultivated. Permanent pastures of white clover and blue grass are more universally used than in the prairie areas of the Middle Western states, on account of the rough topography of the country that prevents many areas from being arable, and, therefore, prevents the use of the rotation pasture.

The soils of the North Atlantic states, as a rule, were not as naturally fertile as the prairie and timber soils of the Mississippi Valley. Many a farm in this region has a

shallow soil with a small percentage of humus, and derived from rock materials that were not rich in all the forms of mineral plant food. The majority of the Middle Western soils have water deposited soils or glacial debris soils in which the soil particles were derived from a great varitey of rock materials, thus making the soils comparatively well balanced in the elements of plant food. But this desirable mixing of soil materials, and the sorting action of water, did not take place in the formation of a great part of the North Atlantic soils. There are several rich valley soil regions in these states, such as the Connecticut River Valley, and the Genessee Valley, but the average hillside or small valley farm was not blessed with as naturally a productive soil as the prairie areas and hardwood timber areas of the Middle Western states.

In addition to this fact about the average soil of this region, there are many soil areas that have been tilled for two hundred years or more, and unscientific soil tillage has taken its toll of soil fertility in many places to a degree that has made many areas relatively unproductive, unless large amounts of commercial fertilizers are used.



A modern dairy barn in New York State.

These facts about the agriculture of the North Atlantic states are given to show that the planning of crop rotations in this agricultural region of the United States is not as easy as in the prairie states of the Middle West. In many cases the specialized types of agriculture practiced do not easily lend themselves to rotation plans of cropping, and in other cases the soils need much special treatment and renovation to make them productive—work that is supplementary to ordinary crop rotation. Crop rotation and systematic field management, nevertheless, are as essential to the agriculture of these states, as a whole, as to the agriculture of the prairie regions of the United States, and there are many soil areas and conditions where crop rotation plans are easily made to systematize the prevailing types of farming.

In the following paragraphs a number of rotation plans are shown for the North Atlantic states.

Rotation Plans for Dairy Farming. The great majority of the dairy farms of the North Atlantic states are not adapted to the use of rotation pastures. In most cases either the permanent pasture is a necessity, on account of rough lands within the farm area, or the conditions of agriculture are such that dairy farming is practiced without the use of pasture lands, as shown in Diagrams XX, XXI, and XXII, previously given. Where dairying is practiced in a very intensive manner and without the use of pasture lands, the plans shown in Diagrams XX, XXI, and XXII are as good as any that can be devised. With slight modifications, perhaps, these plans are adaptable to any of the North Atlantic states.

Where the permanent pasture is to be used in connection with dairying, the following rotation plans are among the best that can be recommended for this region of the United States:

(a) 1—Corn for grain; 2—Corn for silage; 3—Oats and peas (seed down after harvest to clover and timothy); 4—Meadow; 5—Meadow.

(b) 1—Corn for grain; 2—Corn for silage (grass seeds sown when corn is laid by); 3—Meadow; 4—Meadow.

(c) 1—Corn for silage (autumn rye cover crop); 2—Corn for silage (autumn rye); 3—Rye (seed down to clover and timothy); 4—Meadow; 5—Meadow.

(d) 1—Corn for silage; 2—Oats and peas (seed down after harvest to clover and timothy); 3—Meadow; 4—Meadow.

(e) 1—Corn for silage; 2—Oats and peas (autumn rye); 3—Rye (seed down to clover); 4—Meadow.

Rotation Plans for Potato Farming. The same general principles for rotation plans that will make potatoes the chief marketable product of the farm that were outlined in Diagram X, are applicable to potato farming in the North Atlantic states.

In some sections of these states a two-year rotation for potato farming is practiced that is an excellent plan where the chief business of the farm is potato growing. This rotation is as follows:

1—Potatoes (autumn rye).

2—Rye (mammoth clover; green manure).

The clover seed is harrowed in on the rye ground in the spring of the year and the clover crop plowed under in the autumn in preparation for potatoes.

In New Jersey a common four-year rotation including sweet potatoes is as follows:

1—Corn (manured).

2—Sweet potatoes (autumn rye).

3—Rye (seeded to clover).

4—Meadow.

If desired, the proportionate acreage of potatoes in this rotation could be increased by eliminating the corn crop and substituting potatoes. In that event it would be a good plan to grow a cover crop of winter rye between the two crops of potatoes and plow under the foliage of this cover crop in the spring of the year. The manure in this latter rotation would be best applied as a top dressing on the meadow, or spread on the meadow land in the autumn and plowed under in preparation for the first crop of potatoes.

Other rotation plans adapted to potato farming in the North Atlantic states are as follows:

(a) 1—Potatoes; 2—Oats (seed down to clover); 3—Clover meadow.

(b) 1—Potatoes; 2—Corn; 3—Oats and peas (seeded after harvest to clover); 4—Clover meadow.

(c) 1—Potatoes (autumn rye); 2—Rye (seed to clover); 3—Clover meadow.

(d) 1—Potatoes; 2—Beans; 3—Wheat (seed to clover); 4—Clover meadow.

(e) 1—Potatoes; 2—Oats (seed to clover); 3—Clover meadow; 4—Corn (seed to clover when corn is laid by); 5—Clover meadow.

Rotation Plans for Tobacco Farming. Rotation plans for tobacco farming would be very similar to those for potato farming.

In the tobacco growing districts of Connecticut a commonly used rotation is the following:

1—Corn (autumn rye cover crop).

2—Tobacco.

3—Oats or wheat (seed to clover).

4—Clover meadow.

In the tobacco districts of Pennsylvania the following rotation is quite commonly used:

1—Tobacco.

2—Oats.

3—Wheat (seed to clover).

4—Clover meadow.

On soils where the humus content and available nitrogen are low, this rotation could be improved by including a green manure crop in the year when oats occupied the land.

Rotations for Mixed Grain and Live Stock Farming. The standard rotations for this type of farming, shown in Diagrams IX, XII, and XIX, are well adapted to the North Atlantic states. Catch crops for annual supplementary pasture, green manure crops, or cover crops could be included to suit the desires of the farm manager by the methods shown in Diagrams XIV, XV, and XVI.

PROBLEMS AND PRACTICUMS

(1) Prepare a table from the United States Census Reports that will show, in the order of their importance, the values produced by the various agricultural enterprises of the North Atlantic states. What are some of the most important specialized, intensive types of agriculture pursued in the North Atlantic states?

(2) What are the most important "cash crops" of the North Atlantic states? See U. S. Census Reports.

(3) What is the average size of the farms in the North Atlantic states? What per cent of the farm land area in these states is under cultivation? See U. S. Census Reports.

(4) Prepare diagrams and rotation plans that will fully illustrate plans for the following types of farming in the North Atlantic states: Dairy and swine farming with permanent pasture lands and with rotation pastures; intensive dairy and swine farming without pasture lands; specialized potato farm; specialized tobacco farm; and a specialized sheep breeding and sheep feeding farm.

(5) Prepare a diagram that will fully illustrate a rotation plan to be the basis for renovating worn-out land in the North Atlantic states.

CHAPTER IX

ROTATIONS FOR SOUTH ATLANTIC STATES

General Statements about the Agriculture of the South Atlantic States. The South Atlantic states of the United States comprise Delaware, Maryland, District of Columbia, Virginia, West Virginia, North Carolina, South Carolina, Georgia and Florida.

The greater part of the territory within the boundaries of these states has a mild temperate zone climate characterized by a long growing season, a mild, open winter, and having an annual rainfall of forty to sixty inches that is well distributed throughout the year. In the southernmost part of this region there are districts having semi-tropical climatic conditions, brought about by the warm waters of the Gulf Stream. Here many crops are grown that are not found in the Temperate Zone. With the exception of those small areas that have a semi-tropical climate, the South Atlantic states are naturally adapted to the growth of the same temperate zone crops as are found in the North Central and North Atlantic states, and the staple crops, in fact, are very similar. There are certain field crops, such as tobacco, cotton, rice, peanuts, and cowpeas, however, that are staple crops in this territory, that are not found in any great quantity in the North Central or North Atlantic states, while cotton and rice are peculiar to this territory and to the South Central states. Speaking of the South Atlantic states as a whole, it may be said that the climatic conditions are such as to favor the growth of a much greater variety of plant life than is possible in either the North Central or the North Atlantic states.

Agriculture has been pursued in some districts of the South Atlantic states for two hundred years or more. It is an old agricultural region as compared with the South Central, North Central and Western regions. The early settlements in Delaware, Maryland, Virginia, Carolina and Georgia, were all agricultural colonies. The colonists, depended almost entirley on tobacco, rice, other cereals, and live stock products, for their livelihood, and, unlike those of

Photo by courtesy Norfolk and Western Railway.

A typical farm scene in Virginia.

New England, engaged but little in fishing and shipbuilding. The early colonies in the South Atlantic states grew rapidly on the agricultural resources of the country, and agriculture developed more rapidly and more extensively than in the New England colonies.

Great plantations developed where tobacco, corn, wheat, potatoes, rice and cotton, were produced in quantity for export, and where much live stock was fattened on the native

blue grass pastures. The agriculture of the South Atlantic states from 1800 to 1860 was of a high order. The plantations and estates were mainly under the management of an intelligent class of people who lived on the land, and who farmed it carefully and with consideration for its future productivity. The agricultural writings of this early period show that the Virginia, Carolina and Georgia planters understood the value of good tillage, the handling of manures, and the benefits of crop rotation, and that they farmed in a manner that was in accord with much of our modern knowledge of agriculture and soil fertility.

The Civil War of 1861 to 1865 gave the agriculture of the South Atlantic states a serious setback. Many of the leading planters and landowners lost their lives in the war, others lost their lands, and to others the reconstruction period following the war brought discouragements that precluded the carrying on of such agriculture as was possible in the ante-bellum days. Then, too, the rapid and wonderful development of the Middle Western prairies gave the agriculture of the South Atlantic states a setback. Business was dull, many young men went West, political and labor conditions were unsettled, the old men were unready to meet the changed conditions, and so agriculture in the South Atlantic states suffered a decline from which it has not yet wholly recovered.

For fifty years following the Civil War, in parts of the South Atlantic states, the almost continuous growth of cotton on certain soil areas, often under a tenant system of farming, has been an important factor in making many soil areas of the South Atlantic states relatively unproductive. This system of farming encouraged shiftlessness and poor farming methods. The continuous growth of cotton without the use of green manure crops, or alternation with pasture and

meadow crops, lowered the humus content of the soil, checked the continuous liberation of plant food within the soil, assisted soil washing and the leaching of soluble plant food, and eventually made the use of commercial fertilizers a necessity in many places.

The climatic conditions of the South Atlantic states tend to waste the fertility of the soil, when it is cultivated, to a greater extent than in the Northern part of the Temperate Zone. In the Northern part of the Temperate Zone the soil is frozen solid for four to six months in the year, and there is but small opportunity for erosion, soil washing, and the leaching away of soluble plant food during the seasons when the land is not occupied by growing crops. In the South Atlantic states, however, the growing season is much longer and the winter seasons are mild and open, with frequent changes of temperature, and with winter rains and melting snows that run over the plow land to wash the soil and to carry off portions of the soluble plant food.

The combined effect of all these conditions, which have influenced the agriculture of the South Atlantic states, has been to impoverish many soil areas, and to necessitate the extensive use of commercial fertilizers. This condition, of course, is true of but a portion of the land in the South Atlantic states; for there is considerable rich, virgin land still to be put into cultivation in this territory, and there are also many areas of deep, rich bottom land along the streams and tidewater flats that are very fertile. The South Atlantic states, by reason of their mild climate, plentiful rainfall, proximity to great markets, and general adaptability to the growth of a great variety of field, garden, and tree crops, comprise one of the very best agricultural regions of the United States. Agricultural progress has been tardy since the Civil War on account of the political, economic and social

conditions that have retarded all business in the Southern states; but in more recent years the real agricultural possibilities of the South Atlantic states have become realized, and conditions are changing that will make for a better and more permanent system of farming.

The greatest agricultural needs of the South Atlantic states are: (1) Deep plowing and thorough tillage; (2) Cover crops to protect land from erosion between regular crop seasons; (3) Increase of the soil's supply of humus by means of crop rotation and green manures; (4) Systems of mixed farming wherein the staple cash crops, such as cotton and tobacco, shall be alternated with forage crops fed to live stock, and the manure returned to the land; (5) Soil amendment, when necessary, with cheap, ground phosphate rock and potash salts in place of the indiscriminate use of the "complete commercial fertilizer."

Undoubtedly there are many soil areas in the South Atlantic states that have become so impoverished as to need heavy applications of commercial fertilizers and much special treatment to amend plant food deficiencies and to thus make them truly productive; but, generally speaking, the use of thorough tillage methods, green manures, cover crops, and crop rotation systems that shall include forage crops fed to live stock, is what is mainly needed to renovate the old soil areas and make the agriculture of the South Atlantic states permanently productive and profitable. The comparatively recent introduction of the cowpea, soy bean, and crimson clover crops into these states has worked wonders in raising the productivity of the cotton and tobacco lands wherever an intelligent use of these crops has been made in rotation with tobacco and cotton. Cover crops of crimson clover, or green manure crops of cowpeas, are easily introduced into rotations of staple crops in the mild climate of the South, and the

favorable effect on staple crop yields is very marked. The cowpea is pre-eminently the great legume, soil building crop

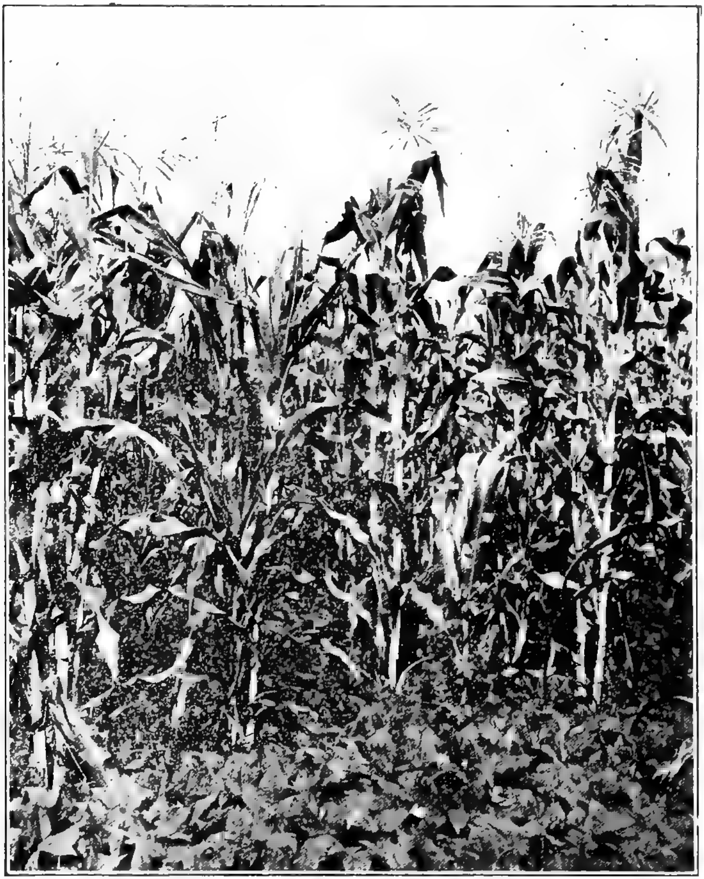


Photo by courtesy "Progressive Farmer."

A "catch crop" of soy beans sown with corn at the last cultivation in the South Atlantic states. The soy beans may be utilized for annual pasture, for a winter cover crop, or for green manure.

of the South, and is not only valuable as a green manure crop but also as a forage or seed crop.

The present day agriculture of the South Atlantic states is generally of a mixed type, although many large areas are given over to the almost continuous culture of special crops. With the exception of South Carolina and Georgia, live stock and dairying are the leading farm enterprises. Cotton leads all other farm enterprises in South Carolina and Georgia, with live stock and dairying ranking second. Cereals and forage crops are the leading crops in all states except South Carolina, Georgia and Florida, cotton leading in South Carolina and Georgia, and vegetable crops leading in Florida. Tobacco is a prominent field crop in Maryland, Virginia and North Carolina, and is produced in all the states of this group. Rice is a prominent crop in North Carolina, South Carolina and Georgia. Sugar cane is prominent in the Carolinas. Truck crops are very important in Delaware, Maryland and Florida. Other crops commonly grown in this territory are: corn, wheat, oats, buckwheat, rye, Irish potatoes, sweet potatoes, peanuts, cowpeas, soy beans, vetches, red clover, alsike clover, crimson clover, alfalfa, timothy, blue grass, Bermuda grass, and Johnson grass.

In the following paragraphs a number of rotation plans are shown for the South Atlantic states that are intended for dairy and general live stock farming, mixed farming with cotton and tobacco as the "money crops," and rotation plans intended to give consideration to special crops.

Rotation Plans for Live Stock Farming The permanent pasture of blue grass, Bermuda grass, or Johnson grass, is more commonly the rule in the South Atlantic states than the rotation pasture of red clover and timothy. For this reason rotation plans for live stock farming in this region should be modeled, in most cases, after the plan shown in Diagram

XIX, using green manure and cover crops to maintain the humus equilibrium of the cultivated lands of the farm. The rotation plans given herewith are planned in connection with permanent pasture lands, and are adapted to dairy farming or general live stock farming.

(a) 1—Corn (crimson clover sown in corn in autumn; 2—Crimson clover for seed, volunteer crop plowed under in autumn, (wheat sown in autumn); 3—Wheat (clover and timothy); 4—Meadow.

(b) 1—Corn silage (crimson clover sown in corn in autumn); 2—Clover hay, sod plowed, corn silage (crimson clover sown in corn in autumn); 3—Clover hay, sod plowed, cowpea hay (wheat sown late autumn); 4—Wheat.

(c) 1—Corn and cowpeas (crimson clover sown at last cultivation for cover crop and green manure); 2—Crimson clover plowed under, cowpeas for hay (wheat); 3—Wheat (clover and timothy); 4—Meadow.

(d) 1—Corn (crimson clover cover crop and green manure); 2—Crimson clover plowed under, soy beans (wheat in autumn); 3—Wheat (red clover); 4—Meadow.

(e) 1—Corn (winter oats); 2—Oats (red clover); 3—Meadow; 4—Cowpeas for hay (wheat); 5—Wheat (crimson clover cover crop and green manure).

Rotation Plans for Mixed Grain and Live Stock Farms.

(a) 1—Corn (wheat); 2—Wheat, cowpeas green manure (wheat); 3—Wheat (red clover); 4—Meadow.

(b) 1—Corn (crimson clover cover crop and green manure); 2—Corn (wheat); 3—Wheat (winter oats); 4—Oats (red clover); 5—Meadow.

(c) 1—Corn (wheat); 2—Wheat (crimson clover); 3—Clover green manure (wheat); 4—Wheat.

Rotation Plans for Tobacco Farming. These plans are intended to give prominence to tobacco as the "money crop" of the farm, but, in order to make a successful rotation, a portion of the rotation should be devoted to crops fed to live stock. Several plans are given herewith, some necessitating live stock to make use of the forage crops, and others depending on green manure crops alone to keep up the humus supply of the soil.

(a) 1—Tobacco (wheat); 2—Wheat (red clover); 3—Meadow.

(b) 1—Tobacco (wheat); 2—Wheat, followed by cowpea green manure.

Photo by courtesy "Progressive Farmer."

Tobacco is an important "cultivated crop" in the South Atlantic states. Under intensive methods of cultivation tobacco will yield values of $100.00 to $300.00 per acre.

(c) 1—Tobacco (wheat); 2—Wheat (red clover); 3—Meadow; 4—Corn with cowpeas.

Rotation Plans for Cotton Farming. These plans are similar to the plans for tobacco farming in that one crop is given prominence in the rotation, and the maintenance of the soil's supply of humus is dependent on the use of green manure crops, or forage crops fed to live stock, or both.

(a) 1—Cotton (crimson clover cover crop and green manure); 2—Corn with cowpeas.

(b) 1—Cotton (crimson clover cover crop and green manure); 2—Corn (wheat); 3—Wheat followed by cowpeas.

(c) 1—Corn with cowpeas (winter oats); 2—Oats followed by cowpeas; 3—Cotton.

(d) 1—Corn with cowpeas (winter Oats); 2—Oats with cowpeas (winter oats); 3—Oats with cowpeas; 4—Cotton.

(e) 1—Corn with cowpeas; 2—Peanuts; 3—Cotton.

Rotation Plans, Miscellaneous Crops.

(a) 1—Potatoes (corn); 2—Oats, followed by cowpeas.

(b) 1—Corn (crimson clover cover crop and green manure); 2—Peanuts.

(c) 1—Corn with cowpeas (wheat); 2—Wheat (crimson clover cover crop and green manure).

(d) 1—Corn with cowpeas (winter oats); 2—Oats (red clover); 3—Meadow; 4—Potatoes.

(e) 1—Corn (crimson clover cover crop and green manure); 2—Peanuts; 3—Oats with cowpeas; 4—Peanuts.

Photo by courtesy "Progressive Farmer."

Peanuts are an important "cash crop" in the South Atlantic states. They are also a fine forage crop, being as productive and nutritious as clover. Hogs can be fattened on the crop in the field. The peanut is a legume and therefore capable of utilizing atmospheric nitrogen by means of the nitrogen gathering bacteria.

Rotation Plans for Rice Farming. Rice is more often grown continuously than in rotation with other crops, but as rice lands are alluvial, deep, bottom lands, the effects of continuous cropping are not as noticeable as in the case of wheat, corn, cotton or tobacco. Modern rice farmers, however, are taking cognizance of the benefits to be derived from crop rotation, and where levees are so constructed as to insure perfect water control, it is profitable to occasionally keep the water off the land and to grow crops other than rice. A rotation plan sometimes used by the rice farmers of the South Atlantic states is the following:

1—Rice; 2—Rice; 3—Rice; 4—Fallow; 5—Corn followed by a pea or bean green manure.

PROBLEMS AND PRACTICUMS

(1) Prepare a table from the United States Census Reports that will show, in the order of their importance, the values produced by the various agricultural enterprises of the South Atlantic states What are some of the most important specialized, intensive types of agriculture pursued in the South Atlantic states?

(2) What are the important "cash crops" of the South Atlantic states? See U. S. Census Reports.

(3) What is the average size of the farms in the South Atlantic states? What per cent of the farm land area in these states is under cultivation? See U. S. Census Reports.

(4) Are there any large areas of virgin land remaining in the South Atlantic states? If so, where located? What crops and types of farming are best adapted to these new regions? See reports and bulletins U. S. Departments Interior and Agriculture.

(5) Prepare diagrams that will fully illustrate practical rotation plans for the following types of farming in the South Atlantic states: Dairy and swine farming with permanent pasture lands, or, fat cattle and swine farming with permanent pasture lands; same types of farming without pasture lands; diversified farming with rotation pastures producing grain, corn, tobacco and live stock; specialized tobacco farm; specialized potato farm; specialized cotton farm; specialized rice farm; diversified farm with cotton as the "cash crop" and with all other crops fed to cattle and swine.

(6) Prepare a diagram that will fully illustrate a rotation plan including cover crops and green manure crops, to be the basis for renovating worn out land in the South Atlantic states.

CHAPTER X

ROTATIONS FOR SOUTH CENTRAL STATES

General Statements about the Agriculture of the South Central States. The South Central states of the United States comprise Kentucky, Tennessee, Alabama, Mississippi, Louisiana, Texas, Oklahoma, and Arkansas.

The climatic conditions within this territory are far from being uniform. Factors causing great climatic variation in this region are: (1) altitude of the various agricultural regions, (2) influence of the warm waters of the Gulf of Mexico on air temperatures, and (3) the proximity of the Western portions of Oklahoma and Texas to the rainless, desert areas of the North American continent. It is impossible, in fact, to give an accurate general description of the climate of the South Central states. Texas, for example, has humid, arid, semi-arid, semi-tropical, mild temperate zone, and cold temperate zone climates within its boundaries. In the mountain regions of Kentucky, Tennessee, and Arkansas, the climate is quite similar to that of the central part of the North Central states, and very dissimilar to the warm, humid climate that exists in the areas of low altitude within this territory. In the Northwestern areas of Texas and Oklahoma the winter season is cold and prolonged, being somewhat similar to the winters of the Western areas of the North Central states, while in Southeastern Texas, Southern Louisiana, and Southern Mississippi, multiple cropping can be practiced the year around.

While there are great climatic variations within the territory of the South Central states, the greater part of those areas best suited to agriculture has a very mild temperate

zone climate, almost semi-tropical in nature, except for winter frosts and the short winter season. The growing seasons are long, the winters short and mild, the mean temperature during the growing season comparatively high, and the rainfall abundant for crop growth. Scant rainfall in Western Texas and Oklahoma necessitates the employment of "dry farming" crops and methods of agriculture, or irrigation in some places where water is obtainable. On the whole, however, the practice of agriculture in the South Central states is greatly favored by abundant rainfall and temperatures favorable to the growth of a great variety of temperate zone plants, as well as many semi-tropical plants.

The so-called "cotton belt" of North America is mainly within the boundaries of the South Central states. Cotton can be profitably grown in every one of the states that comprise this group, and is an important staple crop in all the states of this group except Kentucky and Tennessee. In fact, cotton growing, shipping, ginning, and spinning are the characteristic and outstanding features of business in the South Central states. Tobacco, corn, oats, wheat, and many other temperate zone crops are grown in quantity on the farms of this region, also much live stock is pastured and fed, but cotton is the prominent feature of agriculture in the South Central states.

Another conspicuous feature of agriculture in this region is the large area of fertile, alluvial soil along the Mississippi River and its tributaries. These soil areas are of great extent and have a deep, rich soil of very great fertility. These soils are composed of the silt and organic matter carried by the Mississippi, Missouri, Ohio, Colorado, Tennessee, Red, and Arkansas rivers, from watersheds that comprise the most extensive soil areas of the United States. In times of flood the turbid waters with their load of soil materials would

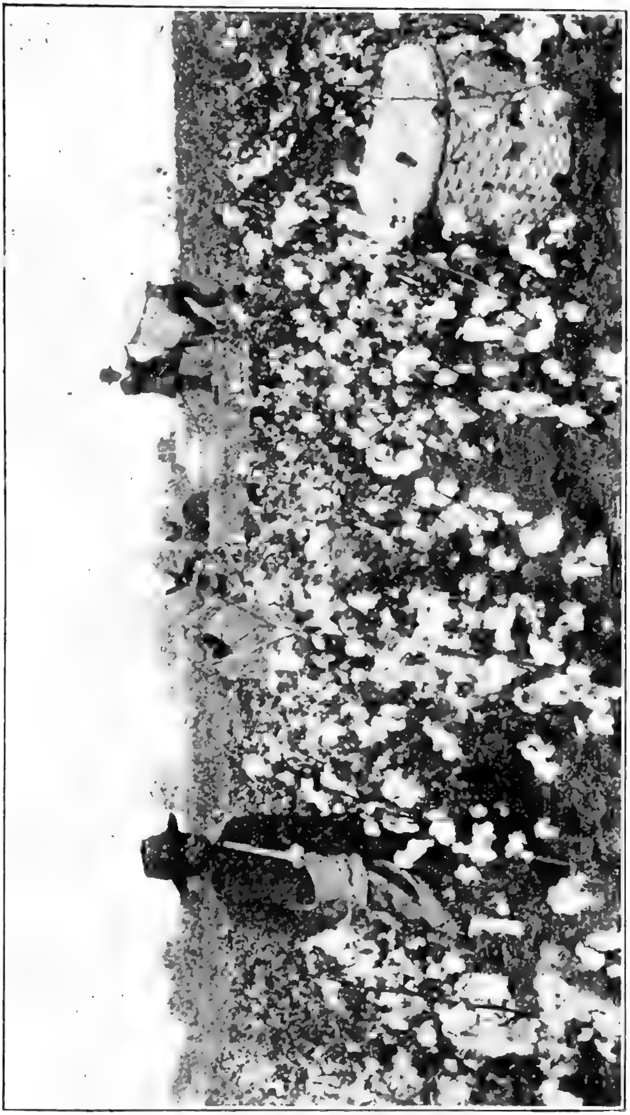


Photo by courtesy "World's Work"

The cotton belt needs a wider use of crop rotation, egume green manures, and live stock, associated with cotton, to increase soil productivity and avoid recurrent financial difficulties arising from a one crop system.

spread out from the main channel over these bottom lands and deposit fresh layers of soil materials brought in from far distant watersheds. Through ages past this process gradually built up great soil areas of wonderful richness and lasting quality, and when the South Central states were first settled, these alluvial river lands were the first developed and put under plow.

Danger from recurrent floods was guarded against by the construction of huge levees and dikes to keep the river in its channel. The amount of sediment annually carried to the Gulf of Mexico by the Mississippi River and its tributaries is so enormous, however, that deposits are constantly being made within the river channel, thereby raising the bed till the problem of confining the river to a definite channel becomes ever more difficult. In many places the river channel, at low water stage, is above the level of the surrounding lands, and thus, when floods occur, the man made levees are not always strong enough to retain the water, and levees break to permit huge floods of water to spread out over the bottom lands as they did before man occupied the land and built levees behind which he could build towns, railways, and farm buildings. Flood danger is a very conspicuous feature of much of the agriculture of the South Central states.

Agriculture in the South Central states, as practiced commercially by the white man, does not date back as early in the history of North America as the agriculture of the North Atlantic and the South Atlantic states. Agriculture had become quite extensive and well developed in the South Atlantic and North Atlantic colonies before any commercial agriculture came into existence in the South Central states. The early Spanish colonies along the Gulf Coast engaged but little in agriculture, and the Indians and Mexicans of the early days were not agriculturists that subdued much land.

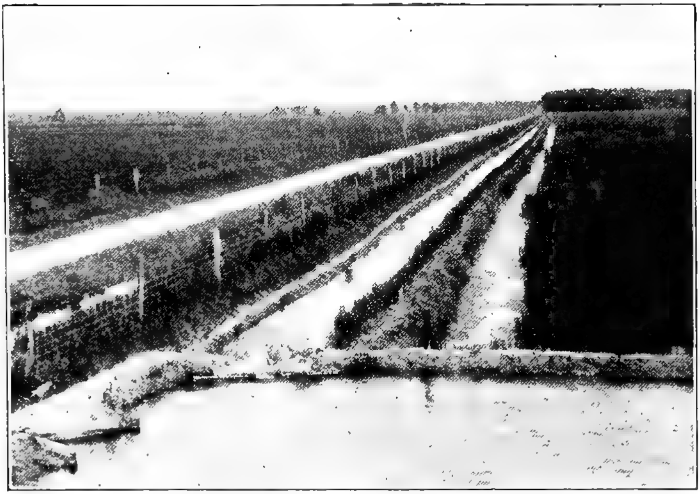


Photo by courtesy St. Louis Southwestern Railway.

Irrigation ditches and dikes for rice irrigation. Rice is sown with the grain drill on a comparatively dry seed bed, the same as wheat or oats. After seeding time the land is flooded from time to time to provide the proper amount of water for the crop's growth.

The development of commercial agriculture did not come in the South Central states until the tide of emigration from the seaboard English speaking colonies began soon after the War of the Revolution.

Kentucky and Tennessee absorbed the first landseekers who came over the Alleghenies from the seaboard colonies, and then in later decades the landseekers swept on to Mississippi, Alabama, Louisiana, Arkansas, and even to Texas territory then under Mexican government. The watercourses facilitated transportation, and colonization was rapid in the early part of the nineteenth century. By 1840 a considerable export trade in cotton and tobacco had developed in the South Central states, the producing lands being chiefly the bottom lands of the main watercourses. Some agricul-

ture developed from the Spanish settlements along the Gulf Coast, but it was the energetic Anglo-Saxon from the seaboard states that established most of the agriculture in the South Central states.

The agriculture of the South Central states, therefore, is not nearly so old as that of the South Atlantic and the North Atlantic states, and few areas have been cultivated one hundred years or more. Such agriculture as does date back one hundred years is confined to a relatively small portion of the South Central states, and many agricultural areas, such as the prairie areas of Texas, Oklahoma, and Indian Territory, have been under cultivation only since 1890 to 1900, during which time a distinct and heavy emigration began from the North Central states into these regions of the South. Compared with the agriculture of the South Atlantic, North Atlantic, North Central, and Western Divisions of the United States, the agriculture of the South Central states is somewhat older than in the Western and North Central divisions, and more recent in development than the agriculture of the South Atlantic and North Atlantic divisions.

As a result of the great natural fertility of many soil areas in this division of the United States, and of the comparatively recent development of agriculture, the percentage of impoverished land in this part is not so great as in either the South Atlantic or the North Atlantic states, and such soils as are somewhat unproductive on account of hard usage in the past, are usually made productive very easily by a rapid increase in the soil's supply of humus and by more thorough soil tillage.

Agriculture in the South Central states has been influenced by many of the same climatic, political, economic, and social conditions that were important factors in molding the agriculture of the South Atlantic states. The mild, open

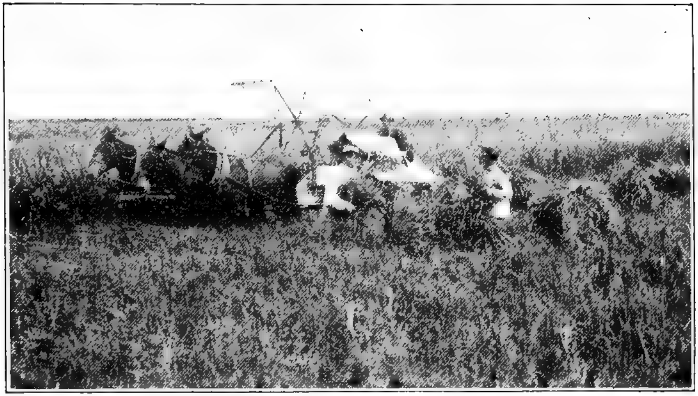


Photo by courtesy St. Louis Southwestern Railway.

Harvesting rice with the grain binder. Prior to harvest the water is drawn off the land and the crop is cut, shocked and threshed by the same methods as are used for wheat and oats.

winters, for example, with changing temperatures, melting snows, prolonged rains, tend to waste soil fertility through erosion and the leaching of soluble plant food, especially on upland, rolling lands. Unless some of the soil areas in this climate are safeguarded from erosion and the leaching of soluble plant food by crop rotation, cover crops, and green manures, a noticeable loss in soil fertility may result. Many soil areas in the South Central states have undoubtedly suffered in this respect; for they have been subjected to much continuous cropping to cultivated crops, such as corn and cotton, that leave the land unprotected against the elements that cause erosion and the leaching away of soluble plant food. As a result some soil areas in this region are impoverished, and need crop rotation, cover crops, green manures, and fertilizer amendments to build them up to a state of high productivity.

Furthermore, the Civil War and the period of reconstruction following the war made a distinct impression on the

agriculture of the South Central states that must be taken into consideration in studying agricultural conditions in the South Central states. Prior to the Civil War the staple crops of the South Central states, cotton, tobacco, corn, and rice, were chiefly grown on the large plantation or estate under the management of the intelligent and skilled planter, who made the plantation his home, and who gave much personal attention to the work of growing crops. Farm labor was largely performed by negro slaves working under overseers. From an economic point of view, the sytem was successful. Good crops were produced, the planters were usually skilled in the art of agriculture, consideration was given to the maintenance of fertility and the farm manager planned for the upkeep of the land that provided him with his home and his business. But the Civil War caused some

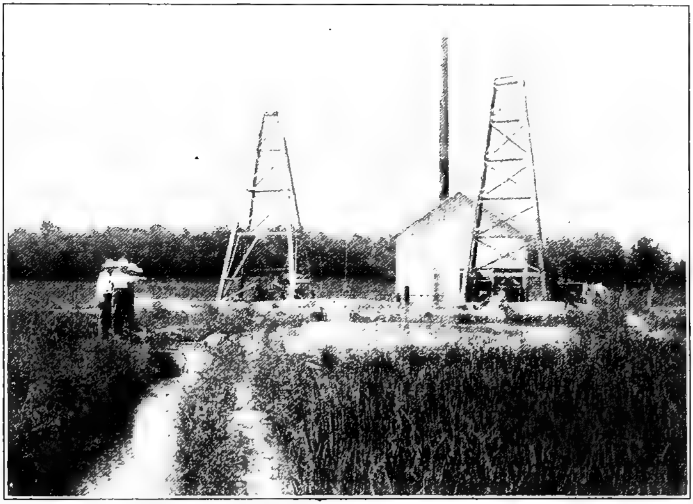


Photo by courtesy St. Louis Southwestern Railway.
Pumping water for rice irrigation in Arkansas.

very radical changes in the agriculture of the South Central states. Many planters never returned from the war; to others who survived the war, the war brought bankruptcy; and still others were helpless, under the conditions of the reconstruction period, and with free negro labor, to pursue the agriculture to which they were accustomed. For a time agriculture was at a standstill. Fields were idle and fallow. The landowner with his large plantation knew not how to sow and reap the crops under the new and changed conditions, and the negro laborer was as nonplused as the planter. Out of this chaos in the agriculture of the South Central states there gradually emerged a new system of agriculture wherein much tenant farming replaced the large plantation. The negro laborer became a tenant farmer on a small tract of land. Some of the old plantations remained intact, and, also, many Northern farmers came South to operate small farms; but, nevertheless, large areas of land went under a tenant system of farming wherein the tenant was generally unskilled, shiftless, and poorly versed in the art of agriculture.

Very naturally these conditions caused a decline in the agriculture of this region. Agricultural progress in many regions of the South Central states has been remarkably slow in the past fifty years as compared with progress in the North Central states. Modern agricultural machinery has not come into universal use and the methods employed in tilling the soil and in growing crops are often antiquated and ill suited to secure the best results. Continuous cotton and corn culture, accompanied by soil erosion and the leaching of soluble plant food, have impoverished many soil areas so badly that the crop is no longer profitable to either tenant or landlord. Experience has shown, however, that the majority of these impoverished soil areas are easily renovated and made productive. The average soil area of this region is naturally

fertile, and unproductivity of the soil can usually be traced to a poor physical condition, lack of a sufficient supply of humus, and to the unavailability of the elements of plant food—conditions that are all easily remedied.

What has been said in previous paragraphs in regard to impoverished soil areas, negro tenant farming, and lack of progress in the agriculture of the South Central states, is not applicable by any means to the whole area included in these states. As a whole, the area is a wonderfully rich agricultural region, still containing much rich virgin prairie and timber land and having developed areas that are farmed by modern methods and with the most modern types of machinery. The agriculture on the Oklahoma and Texas prairie, the rice farming in Texas, Arkansas, and Louisiana, the tobacco farming and horse breeding in Kentucky, the fine alfalfa fields and the fat stock in parts of all these states, and the skillful truck and fruit farming of favored districts in this territory, all bear witness to agricultural progress and successful types of agriculture. The South Central states have some areas that past influences have made backward in agricultural progress and where land is impoverished and unproductive; but, on the other hand, there are many progressive districts practicing up-to-date agriculture, and there is much virgin land still available for the staple crops of the South, namely, cotton, rice, sugar cane, corn, and oats.

The greatest agricultural needs of the South Central states, as a whole are: (1) Better protection from river floods. (2) A more universal use of modern agricultural machinery and better methods of soil tillage. (3) Systems of crop rotation wherein the staple "money crops," cotton, corn, oats, tobacco, rice, and sugar cane, shall be rotated with forage and pasture crops. (4) A more general use of cover crops on the rolling lands to check soil erosion and the leaching of soluble

Photo by courtesy C. V. Piper, U. S. Dept. of Agriculture.

Plowing under cowpeas for green manure. Cowpeas are the pre-eminent soil renovating crop of the Southern states. The humus and nitrogen content of a worn soil can be quickly increased by a systematic rotation plan including occasional cowpea green manure crops.

plant food. (5) A more general use of green manure crops to maintain a "humus equilibrium" in the soil. (6) Soil amendment, when necessary, with cheap, ground phosphate rock and potash salts, in place of the indiscriminate use of the "complete commercial fertilizer."

Flood protection is an immense problem entirely outside the scope of the subject of crop rotation. But, with the exception of this important agricultural problem, crop rotation and systematic field management—in the broadest interpretation of the term—is the remedy for most of the agricultural ills of the South Central states. There may be areas that have become so impoverished through continuous cotton or tobacco culture and shiftless farming methods, or that were so naturally deficient in the elements of plant food, as to

make the extensive use of commercial fertilizers an essential part of a profitable system of agriculture; but experience shows that crop rotation, thorough tillage, cover crops and green manure crops, are the practices most needed in the South Central states to raise the general productivity of the land.

The present day agriculture of the South Central states is extensively varied in character. On the whole, there is probably more mixed farming than special crop farming, as live stock products are the largest agricultural resources of the region. But special crop farming is also very prominent in this region, and some special crop usually predominates in the so-called "mixed" types of farming. In Kentucky, Tennessee, and Oklahoma, live stock is the leading product of the farms, with cereals second in importance. In Texas and Arkansas live stock products lead, with cotton second.

Harvesting sugar cane in Louisiana.

In Alabama and Mississippi, cotton is the leading product, with live stock second. In Louisiana, cotton is the leading product, with sugar cane second in importance. In all the states of this group except Kentucky, cotton is an important crop. In Kentucky, tobacco is the great special crop, and the white and dark Burley tobaccos are world famous. Hemp is also a great staple crop in parts of Kentucky; in fact, about nine tenths of the hemp crop of the United States is grown in Kentucky. Rice is an important special crop in Louisiana and Arkansas. Kentucky is famed for its horses and cattle. Texas, although rapidly being settled and put under plow, is still famous for its range cattle, and live stock products still lead all others by a wide margin. Truck crops are becoming especially important in Southeastern Texas, Louisiana, Mississippi, and Arkansas. All kinds of temperate zone fruits and some tropical fruits are grown in considerable quantity in this region.

The staple field crops of the South Central states are cotton, corn, and oats, and they are prominent in nearly every part of the region. Other important field crops are: alfalfa, cowpeas, soy beans, clovers, peanuts, vetches, sweet clover, timothy, blue grass, Johnson grass, Bermuda grass, brome grass, Irish potatoes, sweet potatoes, wheat, rye, barley, buckwheat, Kafir corn, milo maize, and proso millet.

In the following paragraphs a number of rotation plans are shown that provide plans of cropping wherein cotton, tobacco, sugar cane, and rice are given prominence in the rotation. Other plans are shown for mixed grain and live stock farming, also plans for grain farming in the Western areas of Texas and Oklahoma. Where these rotation plans are not adaptable to a wide territory but only to some special region, the name of the state is given with the plan to indicate that the rotation is not of general adaptability.

Rotation Plans Giving Special Consideration to Cotton. Cotton, corn, and oats are the three great staple crops of the old farming regions of the South Central states, cotton being the universal "cash crop," and corn and oats the feed crops. A majority of the farms in the old cotton belt are small in area, and without considerable re-planning and financial outlay ill adapted to diversified farming with pasture crops and live stock. For these reasons a widely useful rotation in the cotton belt should be a short course rotation without pasture crops; should include the staple crops to which the farmers are accustomed; and should depend on some reliable legume crop used as a catch crop to maintain the humus equilibrium of the soil. The following three-course rotation meets all these requirements and is widely adaptable in the cotton growing areas of the South Central states:

1 — Corn (cowpeas sown at last cultivation and plowed under for green manure); 2—Oats, stubble plowed in summer (cowpeas for hay or ensilage) 3—Cotton.*

Experimental work with this rotation to demonstrate its usefulness in the cotton belt has shown very marked results in increasing soil productivity. Generally, the poorer and more impoverished the soil the more marked have been the results, indicating that the great need of the soil areas in the cotton belt is an increase in their supply of humus and available nitrogen. As a rule the beneficial results are cumulative: that is to say, the crop yields increase gradually up to a maximum that is reached several years after the rotation is begun, indicating that as the humus supplies decay in the soil the plant food is gradually unlocked from the soil materials and made available to crop roots, until a maximum productivity

*The Triennial Crop Rotation System. Hugh N. Starnes. Bailey's Cyclopedia of American Agriculture. Vol. II.

Photo by courtesy C. V. Piper, U. S. Dept. of Agriculture.
Harvesting cowpeas for their seed value. When grown for seed, the crop is planted in rows that can be inter-tilled.

is reached that is limited by the natural fertility of the soil. Some general results may be stated that show the efficiency of this rotation on the soil areas of the old cotton belt. Where the average yield of cotton on the old impoverished soil areas under a continuous system of cotton culture is about ⅓ bale (500 lbs.) per acre, the yield of cotton will often increase to ⅔ bale (1,000 lbs.) per acre after the first cycle of the rotation; to 1 bale (1,500 lbs.) per acre after two rotation cycles; and to 1⅓ bales (2,000 lbs.) per acre after three rotation cycles, thereafter seldom falling below 1⅓ bales (2,000 lbs.) per acre, and sometimes reaching two bales (3,000 lbs.) per acre under very favorable climatic conditions. The yields of corn and oats do not usually increase in proportion to the increase in cotton yield, because cotton is given the most favorable place in the rotation, and yet the increase is

marked and the yields are much higher than under continuous cropping to the staple crops.

Other rotations giving prominence to cotton are given herewith:

(a) 1—Corn with cowpeas; 2—Oats, followed by cowpeas or soy beans; 3—Cotton (crimson clover sown among cotton plants in autumn for cover and green manure crop).

(b) 1—Corn with cowpeas; 2—Oats followed, by cowpeas; 3—Cotton (crimson clover sown among cotton plants in autumn for cover and green manure crop); 4—Crimson clover plowed under; Cotton.

(c) (Mississippi) 1—Cotton continuously with annual vetch in winter between crops of cotton.

(d) 1—Corn with cowpeas; 2—Cotton.

(e) 1—Cotton; 2—Cotton (crimson clover sown among cotton plants in autumn for cover crop and green manure); 3—Crimson clover plowed under; Corn; 4—Oats followed by cowpeas for hay or ensilage.

(f) 1—Cotton; 2—Oats, followed by cowpeas for hay or ensilage; 3—Cotton; 4—Corn (cowpeas sown at last cultivation for green manure).

(g) (Oklahoma) 1—Corn or Kafir corn; 2—Oats followed by cowpeas fall plowed for green manure; 3—Cotton.

Rotation Plans for Diversified Farming. The following rotation plans illustrate a great variety of crop combinations for diversified farming in the South Central states. Some of these plans are adapted to small dairy farms, others to general live stock farms also producing "cash crops" on a portion of the land, and still others are so planned as to have

certain staple "cash crops" predominate in the rotation and to make live stock enterprises of secondary importance.

(a) (Kentucky and Tennessee) 1—Corn (wheat); 2 - Wheat (red clover); 3—Clover meadow.

(b) (Kentucky and Tennessee) 1—Tobacco (rye cover crop and green manure); 2—Rye plowed under, corn (wheat); 3—Wheat (blue grass); 4—Blue grass; 5—Blue grass.

(c) (Kentucky and Tennessee) 1—Corn with cowpeas (crimson clover cover crop and green manure); 2—Crimson clover plowed under, Soy beans (wheat); 3—Wheat (clover); 4—Clover meadow.

(d) 1—Corn; 2—Cowpeas for hay or ensilage (wheat); 3—Wheat (clover); 4—Clover meadow.

(e) Same plan as (c) or (d) but with a fifth field in permanent pasture, the rotation to be planned as in Diagram XIX.

(f) (Kentucky and Tennessee) 1—Tobacco (wheat); 2—Wheat (clover); 3—Clover meadow; 4—Corn (crimson clover cover crop and green manure). If desired, this rotation could have a fifth field in permanent pasture according to plan of Diagram XIX.

(g) (Kentucky) 1—Tobacco (wheat); 2—Wheat (clover); 3—Clover meadow; 4—Hemp; 5—Corn (crimson clover cover crop and green manure). If desired, this rotation could have a sixth field in permanent pasture according to the plan of Diagram XIX.

(h) (Tennessee) 1—Cowpeas (rye cover crop and green manure); 2—Rye plowed under, Cowpeas; 3—Corn (wheat); 4—Wheat (clover); 5—Clover meadow.

(i) (Tennessee) 1—Wheat (clover and timothy); 2—Meadow; 3—Pasture (wheat); 4—Wheat, followed by cowpeas; 5—Corn with cowpeas; 6—Oats followed by cowpeas (wheat).

(j) (Texas and Oklahoma) 1—Corn; 2—Cowpeas for hay or ensilage; 3—Cotton; 4—Oats, followed by cowpeas for green manure. A fifth field in alfalfa or clover and timothy as in Diagram XIX.

(k) (Texas and Oklahoma) 1—Cotton; 2—Corn; 3—Oats (clover and timothy); 4—Meadow; 5—Pasture.

(l) (Texas and Oklahoma Grain Regions) 1—Wheat, followed by cowpeas for hay or ensilage; 2—Oats, followed by cowpeas for green manure; 3—Corn (wheat); 4—Wheat (clover); 5—Clover meadow (wheat).

(m) (Oklahoma Grain and Cotton) 1—Corn; 2—Oats, followed by cowpeas for green manure (wheat); 3—Wheat; 4—Corn with cowpeas; 5—Cotton.

(n) (Oklahoma Grain and Corn) 1—Corn with cowpeas (wheat); 2—Wheat; 3—Oats followed by cowpeas for green manure (wheat); 4—Wheat.

(o) (Oklahoma Grain and Live Stock) 1—Corn (wheat); 2—Wheat (wheat); 3—Wheat (clover and timothy); 4—Meadow; 5—Pasture.

Rotation Plans Giving Special Consideration to Tobacco.

(a) (Kentucky) 1—Tobacco (wheat); 2—Wheat (clover); 3—Clover meadow. On farms of comparatively large size where live stock is an important farm enterprise, this rotation could be used in connection with another field of permanent alfalfa, as in Diagram XVIII.

(b) (Kentucky) 1—Tobacco (wheat); 2—Wheat, followed by cowpeas for hay or ensilage (crimson clover cover crop and green manure); 3—Crimson clover plowed under, Tobacco.

Rotation Plans Giving Consideration to Sugar Cane.

(a) (Louisiana) 1—Sugar cane; 2—Sugar cane; 3—Sugar cane; 4—Corn with cowpeas for green manure.

Rotation Plans Giving Special Consideration to Rice.

(a) (Louisiana and Arkansas) 1—Rice; 2—Rice; 3—Rice; 4—Fallow; 5—Corn and cowpeas.

(b) (Louisiana upland rice) 1—Rice; 2—Rice; 3—Corn with cowpeas.

Rotation Plans for the Grain Districts of Western Texas and Oklahoma.

(a) 1—Wheat (winter oats for pasture and green manure ; 2—Wheat; 3—Oats (sweet clover for cover crop and green manure); 4—Sweet clover green manure and fallow.

(b) 1—Milo maize or Kafir corn (wheat); 2—Wheat (sweet clover cover crop and green manure); 3—Green manure fallow (wheat); 4—Wheat. Either of these rotations could be combined with a permanent pasture of alfalfa, brome grass, or sweet clover, as in Diagram XIX.

PROBLEMS AND PRACTICUMS

(1) Prepare a table from the United States Census Reports that will show in the order of their importance, the values produced by the various agricultural enterprises of the South Central states. What are some of the specialized, intensive types of agriculture pursued in the South Central states?

(2) What are the most important "cash crops" of the South Central states? See U. S. Census Reports.

(3) What is the average size of the farms in the South Central states? What per cent of the farm land area in these states is under cultivation. See U. S. Census Reports.

(4) Are there any large areas of virgin land remaining in the South Central states? If so, where located? What crops and types of farming are best adapted to these new regions? See reports and bulletins U. S. Departments Interior and Agriculture.

(5) Prepare diagrams that will fully illustrate practical rotation plans for the following types of farming in the South Central states: Diversified farming with rotation pastures producing grain, corn and live stock or dairy products; same type of farming with permanent pastures; diversified farming with cotton or tobacco as the "cash crop;" specialized cotton farming; specialized tobacco farming; specialized rice farming; specialized sugar cane farming.

(6) Prepare a diagram that will fully illustrate a rotation plan devised for the particular purpose of renovating worn cotton lands in the South Central states.

CHAPTER XI

ROTATIONS FOR WESTERN STATES

General Statements about the Agriculture of the Western States. The Western states of the United States comprise Montana, Wyoming, Colorado, New Mexico, Arizona, Utah, Nevada, Idaho, Washington, Oregon, and California.

This vast territory, tributary to the Pacific seaboard, has a variety of climatic conditions that range from arid to humid as regards moisture, and from semi-tropical to north temperate as regards temperatures and the character of plant life. No other territory on the North American continent has such a wide variation in rainfall, temperatures, and character of plant life as this one designated as the Western states. Those portions in the lower altitudes in New Mexico, Arizona, Nevada, Idaho, Wyoming, Colorado, Utah, and California, are desert areas where rainfall is so scant as to be an absolutely negligible factor in agriculture, where such rain as does occasionally fall is quickly evaporated in the high temperatures, and where such desert loving plants as the cactus, greasewood, and the sagebrush are the only indigenous forms of plant life. In many of these desert areas, moreover, the supply of water for irrigating purposes is very limited, and there are millions of acres that never can be used for agricultural purposes.

In contrast to these desert areas there are large areas on the North Pacific Slope, and also on the higher altitudes of some of the mountain ranges, where the rainfall is abundant for temperate zone plant life and where the evaporation of soil moisture is not such as to cause almost total loss of the moisture precipitation as in the desert areas. In these humid

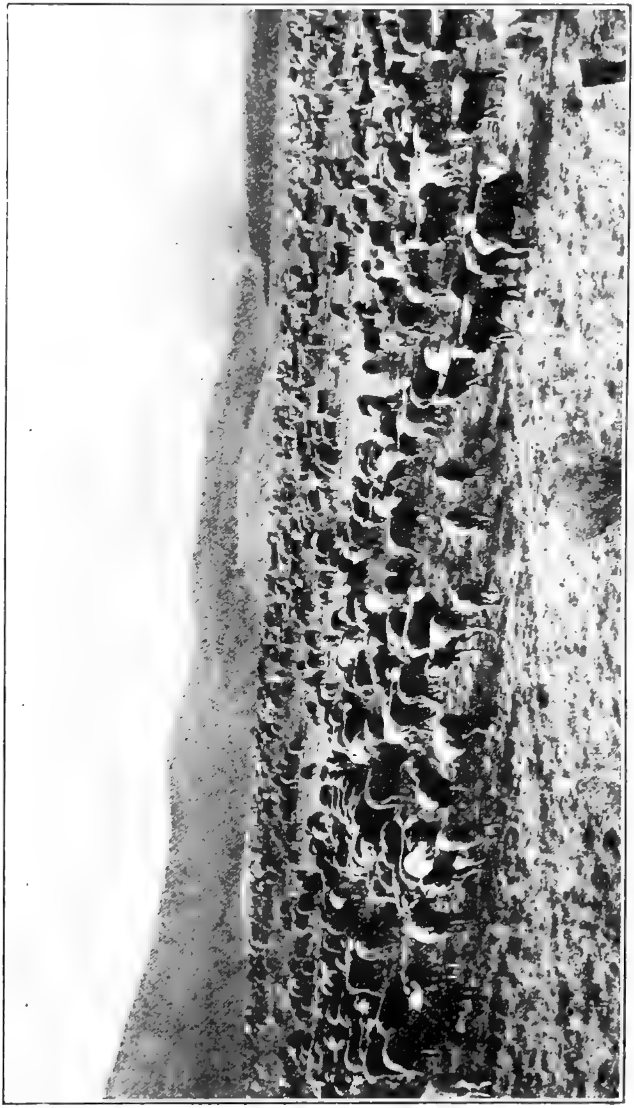


Photo by courtesy Northern Pacific Railway.

Sheep on the range in Oregon. Large bands of sheep are run on land unfit for agriculture and wintered largely on alfalfa hay grown in the valleys.

sections of the Western states a great variety of temperate zone plant life is found that is quite similar to the plant life of the humid sections of the North Central states. Generally speaking, the winters are less severe in the humid sections of the Western states than in the North Central states, and there is less snowfall.

Semi-tropical temperatures and crops are found in several places in the Western states, notably Southern California, Southern Arizona, and Southern Nevada. In these regions, however, the rainfall is not sufficient for profitable agriculture or horticulture, and irrigation is essential to crop or tree growth. The frost free conditions of these regions is mainly due to their proximity to the warm waters of the Japan Current and the trade winds which pass over these warm waters and modify the air temperatures inland.

The Japan Current is also a noticeable factor in modifying the climate of the North Pacific coast, and its influence on air temperatures and rainfall can be noted as far North as Alaska, and East well into the Rocky Mountain districts. In Montana, for example, the climatic conditions West of the Rocky Mountains are much different from those on the Eastern side of the state. West of the Rocky Mountains, and in the mountain valleys, the winters are comparatively mild and the rainfall more abundant than in Eastern Montana. Cold air and storms come into this territory more often from the East and the Northeast than from the West and Northwest. In Oregon, Washington, and British Columbia, the winters are milder, and extremes in temperatures less marked than at similar latitudes in the North Central states or the central provinces of Canada.

Altitude is a very important factor in causing climatic variation in the Western states and, therefore, modifies agricultural conditions. Arable land areas, either having

sufficient rainfall for crop growth or available water for irrigation, exist in the Western states at altitudes ranging from a few feet above sea level to 6,000 or 8,000, feet above sea level. Regions of high altitude have a comparatively low mean temperature, with cool nights, small extremes in temperature, and with greater rainfall than regions of low altitude in the same latitude. Thus it is not uncommon in parts of the Western states to find warm valleys at low altitudes where semi-tropical and southern temperate zone crops will flourish, and agricultural areas at higher altitudes where the only crops that can be grown are the hardy cereals, grasses, and forage crops of the northern temperate zone.

Great plateaus or plains are found in the Western states, at altitudes of 1,000 to 5,000 feet above sea level, that are semi-arid in climate, and where the native vegetation consists mainly of short grasses such as the bunch grass and the buffalo grass. The annual precipitation of moisture in these regions is from ten to twenty inches, most of which falls in the spring and early summer, the balance falling in the late autumn and winter. The greater part of these areas can never be supplied with irrigating water, and such agriculture as is pursued must depend on the rainfall. Fortunately, however, such rains as do fall come in the seasons when crops are most in need of moisture, and the generally cool temperatures do not cause excessive evaporation. Thus the so-called "dry farming" methods of agriculture which provide deep tillage, occasional bare fallows, and thorough surface tillage to conserve moisture, are usually successful, and permit the profitable growth of many temperate zone cereals, grasses, and forage crops.

The agriculture of the Western states is new as compared with the agriculture of the North Atlantic, South Atlantic, South Central and North Central states. Few agricultural

areas of any importance have been under cultivation for fifty years. Some scattering agriculture was practiced prior to the Civil War near the old Spanish missions, also by the Mormon colonies in Utah, and by some of the stranded gold seekers of 1849; but commercial agriculture in the Western states received its first great impetus with the coming of the trans-continental railways in the decade 1870 to 1880. From that time to the present the agricultural development of the Western states has been marvelous. It was unusually rapid compared with the development of the older regions on account of the fact that modern agricultural machinery was at the service of the Western pioneer, and his efficiency in subduing land was greater than in the earlier periods of American history.

The agriculture of the West has developed into vast proportions in a night, as it were. In its early stages it was almost entirely pastoral, with the exception, perhaps, of the great wheat farms that quickly came into being in Northern California and in Washington and Oregon. Cattle ranching in the earliest days, and then sheep ranching as well, came to be the great agricultural industries. There were millions of acres of free range, abundant water in the mountain streams, shelter in the valleys, and plenty of irrigating water for the early settler to employ in producing alfalfa for winter feed. When the gold seeking craze subsided in the West, thousands of prospectors were bankrupt and unable to leave the country. From necessity many of these men turned to ranching. With countless acres of range, with freedom from the financial burdens of the Eastern farmer who paid interest, taxes, and machine bills, these ranchers of the early days in the West had but to wait for the natural increase in their live stock to make them a living and sometimes to make them very wealthy. And it was the spirit of the West to lend a helping

Cattle on the range in Montana. A typical scene in the old ranching days.

Photo by courtesy Montana Ranches Company.

hand to the beginner. The well established rancher would provide the beginner with a small herd or flock for half the natural increase, and so ranching flourished and grew to enormous proportions in all of the Western states.

While live stock ranching was developing in the West there was much agricultural and horticultural development also taking place. The wheat fields of Northern California, Northern Idaho, Washington, Oregon, and certain favored valleys in the Rocky Mountain regions, produced wheat in sufficient quantity to become a recognized factor in the world's wheat markets. Large areas of land, capable of irrigation by primitive methods, were sown to alfalfa to provide winter feed to supplement the range grasses in live stock production. In other places where soil and climate were found to specially favor the fruit crops of the temperate and semi-tropical zones, orchards were planted, and, in a short space of time, the horticultural enterprises of the West assumed large proportions.

When the railways had laid their steel paths throughout the Western states, and when the pioneers had proven conclusively the agricultural and horticultural possibilities, the small farmer, the truck grower, and the orchardist began to steadily encroach on the great, open live stock ranges of the country. The best land was soon homesteaded, water rights on the streams available for irrigation were filed with the courts, and the patches of grain, alfalfa, and tree crops grew up rapidly in the wildernesses where once the cattleman and the sheepman were supreme. Ranching died hard on the Western range. It gave way to the farmer only after a bitter struggle, but the thousands of small farmers would not be denied, and to-day there is little of the old time stock ranching in the West. Stock grazing is still supreme in those sections of the West too arid for dry farming crops, and where irrigat-

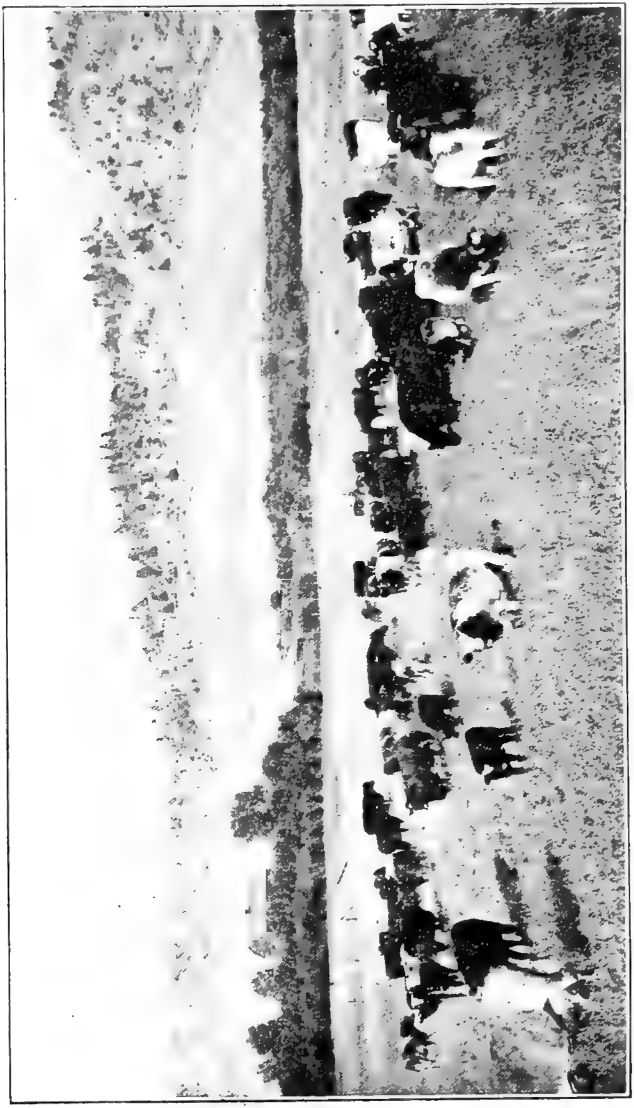


Photo by courtesy Northern Pacific Railway.

The modern live stock enterprises of the Western States depend largely on the government forest reserves for summer pasture. The range pasture is supplemented by meadow aftermath on the irrigated farms, with alfalfa the mainstay for winter feed.

ing water is not plentiful; but the richest grass areas of the Western range are now interspersed with countless farms that stand in the path of the old time system of ranching. Much live stock is still produced in the West, but under different conditions. The national forest reserves in the mountainous areas still provide large grazing tracts where stock can be pastured for six to eight months in the year at a nominal cost. But the herds and flocks have become smaller in size and are largely owned by the farmers who grow grain and alfalfa in the valleys, fatten their stock on the farms, and use the range on the forest reserves to supplement the tame grass pastures.

The extensive development of grain growing in the semi-arid regions of the Western states since the year 1905 is one of the conspicuous features of agricultural development in the West. Hundreds of thousands of acres are now sown to winter wheat, flax, oats, rye, and barley, that but a short time ago were covered with a light growth of plains grasses. Winter wheat production, especially, has proven highly successful in many of these semi-arid regions, and crops are grown that surpass in quality the winter wheat of the North Central and South Central states, and that often excel in yield per acre. Montana has become the banner flax state, and there is a vast acreage of land adapted to flax that still invites the plow.

In the present day agriculture of the Western states live stock production is still the leading agricultural enterprise, although, as previously noted, the methods of live stock production have undergone a change from exclusive grazing to a system that combines much hay and forage production with grazing. Second in importance comes hay and grain production, and third, dairying. Fruit and truck crops are of sufficient importance in many regions to compete with

dairying for third place in the leading agricultural industries of the Western states, and, in California, live stock production, grain and hay production, and fruit and truck crops, are of approximately equal importance. Alfalfa, more than any other crop, is the universally grown crop of the Western states. Many farms are devoted exclusively to alfalfa production and the hay is fed out in the winter season to range live stock or baled and shipped to the cities, the fruit growing districts, the mining camps, and the lumber camps. Almost every ranch in the Western states produces alfalfa except the exclusive fruit and truck ranches, the dry farming grain ranches, and a few areas in the humid region of the North Pacific slope, where wheat is still grown to the exclusion of nearly all the other field crops. The great majority of the irrigating ditches of the Western states carry water to fields of alfalfa. Alfalfa is to the Western states what cotton is to the South Central states—the staple crop of the country.

The rapid development of irrigation in the Western states is a very conspicuous feature of Western agriculture, and the possibilities for agricultural development in the West through irrigation are only at their beginning. Irrigation is old, considering the relative age of Western agriculture. In fact, the earliest agriculture in the Western states was irrigated crop growing practiced in Utah by the Mormons in the decade prior to the Civil War. The early Mormon colonies became adepts at irrigation long before the real colonization movement started into the Western states. Prior to the irrigation work begun by the Mormons, some irrigation was practiced by the scattering Mexican settlers in Lower California, the Spanish monks of the missions, and even by the native Indian tribes of the Western states. From these early beginnings in irrigation work the practice spread

Photo by courtesy C. M. and St. P. Railway.
Irrigation flume conducting water from the mountain watersheds to the valley farms.

rapidly with the coming of the gold seekers and with the later advent of the hordes of genuine land seekers.

Private water rights, private ditches, and a wasteful use of irrigating water were characteristic of the early days in Western agriculture, and are still features in many of the newly settled districts. But, as time passed, the irrigation work became more organized and co-operative in nature. Co-operative Water Users' Associations, and State and Federal Government Irrigation Projects began to take the place of unorganized, individual use and control of irrigating water. The waste of water was checked, and, by checking waste as well as controlling the water on the watersheds by means of reservoirs and flumes, the area of land that could be put under ditch was enormously increased.

At the present time the projected plans for irrigation work in the Western states are of vast size and extent. Huge dams and reservoirs are being constructed that will store up enormous supplies of melted snow and rain water in the

mountains that now run to waste for a large part of the year, and release it gradually, and as needed, to the tributary farm lands. In many sections the engineering works pertaining to irrigation are highly perfected, and every drop of snow and rain water that accumulates on the mountain water-sheds is conserved and utilized on the adjacent arable lands. In many other sections irrigation is crude and primitive, water is wasted, and a large part of the available water supply is allowed to run off into the main water-courses. As the West settles, however, and as wealth accumulates, hundreds of great engineering projects will undoubtedly arise that will conserve the water supplies on the mountain water-sheds and make possible the irrigation of ten acres where one acre is now under ditch. The future will undoubtedly see millions of acres of Western land, now arid or semi-

Photo by courtesy Northern Pacific Railway.

An irrigation dam in the Western states. The acreage of land that may be irrigated from any watershed is greatly increased by dams and reservoirs that prevent a rapid run-off of snow water.

arid, under ditch and yielding rich harvests of cereal, hay, and fruit crops.

The soil areas of the Western states are, generally speaking, of sedentary and colluvial origin. That is to say, the soils are mainly composed of local rock materials eroded from the adjoining mountain ranges, or decayed rock materials underlaid by the native rock. In some regions there is volcanic ash soil that was spread out from volcanoes now extinct. There are comparatively few soil areas that have resulted from the activity of glaciers, as is the case of the soil areas in the North Central states. There are many areas of alluvial soil (water deposited soil) along the streams, but no such great, widespreading areas of alluvial soil as are found in the old lake bed of Lake Agassiz in Minnesota and North Dakota, or the alluvial lands of the Mississippi River in the South Central states. For these reasons the average soil area of the Western states does not contain such a mixture of rock materials as many of the glaciated and alluvial soil areas of the North Central and South Central states.

Many large soil areas in the Western states are composed almost entirely of decayed limestone with little if any admixture of granite rock materials. These soils are usually rich in phosphorus and weak in potassium and nitrogen, and, therefore, somewhat one-sided in their supplies of plant food. This condition is less injurious to agricultural soils than a condition where the soil is weak in phosphorus, because field crops draw heavily on phosphorus, and a soil weak in its natural supplies of phorphorus is more difficult to maintain in a condition of high productivity than a soil weak in potassium and nitrogen. The average soil, especially in the arid and semi-arid regions, is very rich in its supplies of available plant food. Through ages past these soils have decayed

and disintegrated without loss of available plant food through the leaching that might occur in regions of greater rainfall.

On the other hand, the average Western soil is low in nitrogen content and in its supply of natural humus. Few Western soils are black in color, for there is not sufficient humus in the virgin soil to cause much black color. With no luxuriant growth of wild grasses to decay and form humus, these Western soils are commonly brownish in color—the weather beaten color of the native rock materials. Men who are accustomed to the black prairie soils of the Middle West find it hard to believe that the brown colored soils of the Western states are productive, for soil color is to them an index of fertility. But color is not an infallible test of soil fertility. The weak appearing soils of the Western states produce bountiful harvests, if sufficient rainfall can be stored in the plowed land or sufficient irrigating water is available for the needs of crop growth.

There are practically no impoverished soil areas as yet in the Western states. The agriculture is too new. But there are certain indications that point toward impoverished soils, unless greater consideration is given in the future to the problems of soil fertility. The very fact that the most of the Western virgin soils are rich in available plant food, and at the same time deficient in humus, is an indication that they can be quickly impoverished, unless careful consideration is given to building up the humus supply, and also to preventing the loss of soluble plant food through wasteful methods of irrigation. Once the stored up supplies of available plant food in the soil have been exhausted, soil productivity will surely decrease, unless humus is put into the soil by means of crop rotation, live stock manures, and green manure crops; for humus is an absolutely essential factor in

maintaining the supplies of available plant food in the soil.

Then, too, irrigation, unless carefully safeguarded, is an active agent in leaching away the soluble plant food of the soil. If an excessive amount of irrigating water is used on rich soils, available plant food in excess of what the crops use is carried off the land and lost. Neither of these conditions is markedly apparent as yet in Western agriculture, but these forces are, nevertheless, constantly at work, and impoverished soil areas will result, unless the safeguards provided by crop rotation, green manures, and careful methods of handling irrigating water are provided in the years to come.

The so-called "dry land agriculture" of the Western states is so new that no thought has ever been given to its future or the future productivity of the soils on which it is practiced. The problems of the "dry land" farmer up to the present time have been entirely the problems of getting the wild sod broken, the choice of crops, the amount of seed to sow per acre, and the tillage methods that would best conserve the rainfall. Further than this the "dry land" farmer has never thought. But the coming years will bring the problem of soil fertility as well. "Dry farming," as now practiced in the Western states, takes a heavy toll of plant food from the soil and returns nothing to maintain a fertile condition. The cereal products are sold from the land, the straw stacks burned, the occasional bare fallows assist the oxidation of such humus as is in the soil, and no animal manures, sod crops, or green manures are used to maintain a humus equilibrium in the soil.

These practices will bring trouble to the "dry land" farmer of the future; for even the richest soils will eventually be put into a relatively unproductive condition by these methods of cropping. To provide a safeguard against unproductivity of semi-arid, dry farming soil areas is not nearly so easy as for

Photo by courtesy Montana Ranches Company.

Dry land winter wheat on the bench lands of Montana.

soils in a humid climate or in arid or semi-arid climates, where irrigation is practiced. Pasture and hay crops are relatively unprofitable, and sometimes entirely impractical, under "dry land" conditions of agriculture, and the use of green manure crops, as catch crops between regular grain crops is usually impractical, on account of the scant rainfall which prohibits the growth of more than one crop in a season.

About the only practical plan that can be used in these regions to maintain the "humus equilibrium" of the soil, and thus maintain a high state of productivity, is to occasionally grow a green manure crop that will produce a comparatively heavy foliage before the period of summer drouth arrives, and to plow under this crop while green, bare fallowing the land for the remainder of the season. Various crops can be used in the Western states for this purpose, such as winter rye, winter vetch, and sweet clover, or spring sown crops, such as field peas, vetches, and buckwheat. This practice will give all the benefits of the bare fallow and at the same time incorporate sufficient humus in the soil to benefit the water holding capacity of the soil, and to assist the processes of soil decay that liberate the plant food and make it available to crop roots.

Mixed, or diversified farming, as the term is used in the Middle West, is not common in the Western states. It is found occasionally, but is not the common type. Western agriculture is generally specialized. There are large numbers of alfalfa farms, grain farms, sugar beet farms, potato farms, and truck and fruit farms, but not a large number of farms where several kinds of field crops as well as live stock are produced on the same farm. Favorable soil and climatic conditions for special crops have caused much agriculture to develop along special lines. Special types of agricultural production and marketing have been more thoroughly

organized in the Western states than in any other region of the United States. "Dry land farming" in the semi-arid regions, also, does not easily permit a mixed type of farming, but tends to cause a system of almost continuous grain culture. Many of the special types of agriculture are so firmly established in the West, and the soil and climatic conditions are so favorable for special crops, that the future is not likely to see such a general trend toward diversified farming as is taking place in the North Central states. In the humid regions of the Pacific Slope country, and also in many of the irrigated sections of the Northern part of the Western states, diversified farming will undoubt-

Photo by courtesy Washington Agricultural Expt. Station.

Harvesting wheat in Washington with the combined harvester and thresher. Extensive and continuous wheat growing, as represented in this picture, is being supplanted by a mixed type of farming.

edly increase in extent and popularity in the years to come. Dairy farming, for example, is greatly undeveloped in the Western states and production is behind the demand, causing large imports from the Eastern states.

The fact that Western soils are, as a rule, low in their natural supply of humus will necessitate more diversified farming and the use of green manure crops in the future to maintain a condition of high soil productivity. Western agriculture at the present time is largely appropriating the accumulated stores of available plant food in the soil and paying but little attention to the future productivity of the land. As its agriculture ages, and as all the virgin lands are put into cultivation, the West will eventually be forced into systems of farming that will recognize the future conditions of soil productivity. If special types of agriculture are maintained in the future, as many of them doubtlessly will be, the use of green manure crops will have to be employed to maintain the humus supply of the soil and a physical soil condition that will liberate the reserve plant food as needed by crops. In other places, where all the conditions favor diversified agriculture, the use of pasture and forage crops including deep-rooted legumes, together with live stock enterprises under farm conditions, will undoubtedly replace much of the special crop farming now being carried on.

The staple field crops of the Western states are: alfalfa, clover, vetches, timothy, brome grass, field peas, wrinkled peas, winter wheat, spring wheat, rye, barley, oats, flax, Irish potatoes, sugar beets, and also corn, milo maize, and Kafir corn, of secondary importance. There are numerous regions where corn is a profitable crop; but the production is very small, because the land can be made to bring greater returns in alfalfa, truck crops, or fruit crops. Some corn is produced in the river valleys of South Central Montana, also

in the valleys of low altitude in California, Washington, and Oregon; but the corn crop of the Western states is insignificant as compared with the small grain and hay crops. Where live stock is fattened on the farms, the pea crop is a common feed crop that takes the place of corn as used in the Middle Western states. Peas yield abundantly, mature nicely in the dry climate, are cheaply produced, and are a rich, fattening food. The crop is often "hogged off" in the field with excellent results or is cut and stacked for winter feed.

Pork and beef production can undoubtedly be carried on as cheaply, if not more cheaply, in the Western states than in the corn belt. The combination of alfalfa pasture, alfalfa hay, pea grain, pea pasture, and oats or barley, all cheaply produced in comparison with corn, cannot be excelled for the purpose of growing and fattening live stock. Corn is coming into favor in many of the humid sections of the Pacific slope country as a silage crop, but, generally speaking, the Western country is not a corn growing region. In comparatively high altitudes the mean temperatures are too low and the nights too cool for successful corn culture, and in the warm valleys where the mean temperatures are favorable to corn culture, the land is usually occupied by crops that are more profitable than corn to the farmer.

The cool temperatures of many parts of the Western states, however, are as favorable to small grain production as the high mean temperatures of the growing season in the corn belt are favorable to the corn crop. The weight per bushel and the yield per acre of small grains in the Western states average higher wherever there is sufficient moisture to mature a crop than in the other agricultural regions of the United States. Field peas and wrinkled peas, also, produce more abundantly in the cool temperatures and the dry air of many sections of the Western states, and the crop is easier

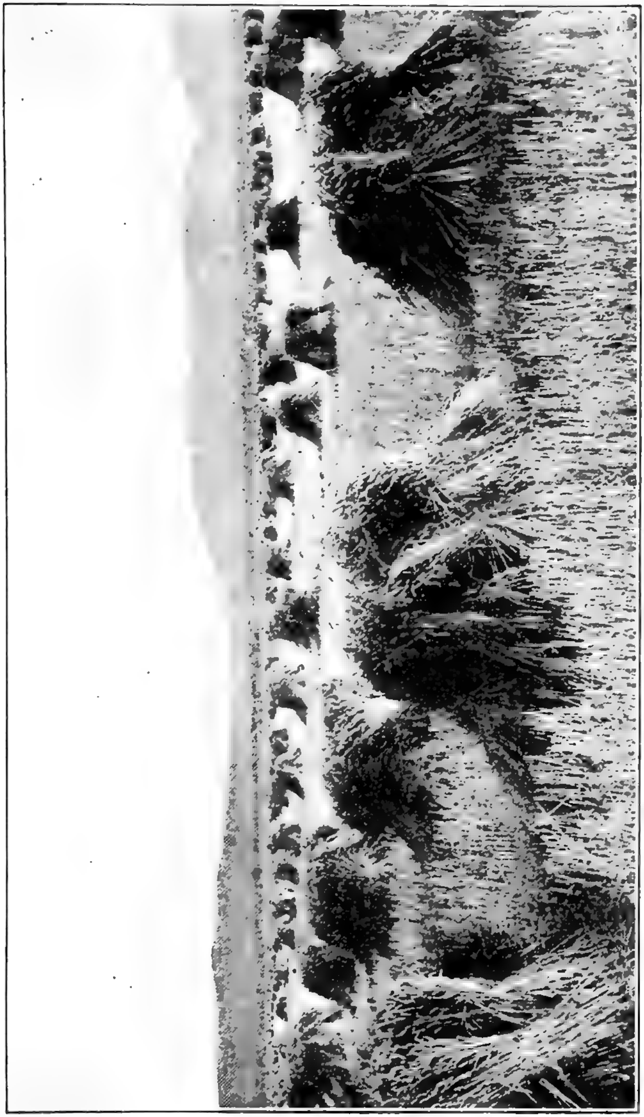


Photo by courtesy Montana Ranches Company.

An irrigated field of wheat in Montana.

to handle and cure properly. Cotton can be grown successfully in many parts of the Western states where altitudes are low and the growing season warm and long. The crop is not extensively grown, however, because, where conditions are favorable for cotton production, other crops such as fruit and truck crops are more profitable, and the areas that can be irrigated are limited.

In the following paragraphs a number of rotation plans are shown that are grouped in a general way for the humid, non-irrigated lands, the semi-arid, non-irrigated lands, and the arid or semi-arid irrigated lands of the Western states. In some cases the name of the state is given with the rotation to further show the region to which the plan is adapted and to show a plan that makes use of the local staple field crops. It should be understood that not many of these plans are now in use in the Western states; for agriculture there is, as previously noted, too new and too specialized to have widely adopted the use of systematic schemes of crop rotation. These plans are based on the tendencies that now exist, the staple crops and the adaptable soil renovating crops of this region, and on the well recognized needs for the future agriculture of the Western group of states.

Rotation Plans, Humid Regions of the Western States.

(a) (Oregon) 1—Corn for silage; 2—Oats; 3—Wheat (clover and timothy); 4—Meadow; 5—Pasture.

(b) (Oregon) 1—Oats; 2—Oats; 3—Wheat (clover); 4—Clover meadow.

(c) (Oregon) 1—Corn for silage; 2—Oats; 3—Wheat (clover); 4—Clover meadow.

(d) 1—Wheat; 2—Oats (vetch); 3—Vetch hay; 4—Wheat (vetch cover crop and green manure).

(e) 1—Wheat; 2—Wheat (vetch); 3—Vetch hay; 4—Wheat; 5—Oats (vetch cover crop and green manure); 6—Green manure fallow; 7—Wheat.

(f) 1—Wheat: 2—Oats (vetch); 3—Green manure fallow.

(g) 1—Wheat; 2—Oats; 3—Barley (clover and timothy); 4—Meadow; 5—Pasture.

(h) 1—Wheat (vetch); 2—Vetch hay; 3—Oats; 4—Peas; 5—Wheat.

The following rotation plans designated as (i), (j), (k), and (l) are plans specially adapted to the state of Washington, and are adaptable to certain of the non-irrigated districts where the rainfall is abundant, and also to regions where rainfall is scant, but where irrigation is practiced.

(i) 1—Corn; 2—Peas; 3—Oats (winter vetch); 4—Vetch hay. If desired, this four-course rotation could be combined with a fifth field in alfalfa or timothy and clover as in Diagram XVIII.

(j) 1—Corn; 2—Corn; 3—Oats (clover and timothy); 4—Clover meadow; 5—Pasture.

(k) 1—Corn (winter vetch); 2—Vetch hay; 3—Potatoes; 4—Oats (clover); 5—Clover meadow.

(l) 1—Oats; 2—Peas. Alfalfa for four to eight years in a third field as in Diagram XVIII.

Rotation Plans for the Non-irrigated, Semi-arid Regions of the Western States.

(a) 1—Wheat (sweet clover in autumn on disked stubble); 2—Green manure fallow deep plowed early summer; 3—Flax, early fall plowed (fall wheat); 4—Wheat (sweet clover in autumn on disked stubble); 5—Green manure fallow plowed early summer (fall wheat).

(b) 1—Wheat (sweet clover in autumn on disked stubble); 2—Green manure fallow early summer plowed (fall wheat); 3—Wheat, early fall plowed (fall wheat).

(c) 1—Wheat (sweet clover in autumn on disked stubble); 2—Green manure fallow plowed early summer (fall wheat); 3—Wheat, stubble fall plowed; 4—Sixty-day oats, stubble early fall plowed (fall wheat). Wherever practical this four-course rotation could be combined with a fifth field of alfalfa, brome grass, sweet clover, or timothy, for pasture and meadow, according to the plan of Diagram XIX.

(d) (New Mexico) 1—Barley; 2—Pea or vetch green manure fallow; 3—Kafir corn or milo maize.

(e) (New Mexico) 1—Barley; 2—Pea or vetch green manure fallow; 3—Oats; 4—Kafir corn or milo maize.

(f) (California) 1—Wheat; 2—Barley (winter vetch); 3—Vetch green manure fallow.

(g) (California) 1—Wheat (winter vetch); 2—Vetch green manure fallow; 3—Barley; 4—Milo maize or Kafir corn.

(h) (Utah) 1—Oats; 2—Pea or vetch green manure fallow; 3—Barley.

(i) (Utah) 1—Oats; 2—Pea or vetch green manure fallow; 3—Barley; 4—Corn or potatoes.

(j) (Colorado) 1—Barley; 2—Pea green manure fallow (fall wheat); 3—Wheat; 4—Milo maize or Kafir corn.

Rotation Plans for the Arid and Semi-arid, Irrigated Lands of the Western States.

(a) (Montana) 1—Oats; 2—Peas; 3—Oats; 4—Peas; and a fifth field in alfalfa as in Diagram XVIII.

(b) (Montana) 1—Oats; 2—Barley (clover); 3—Clover meadow; 4—Oats; and a fifth field in alfalfa according to the plan of Diagram XVIII.

(c) (Montana) 1—Oats (mammoth clover, for fall pasture or green manure); 2—Barley; 3—Peas; 4—Oats.

(d) (Montana) 1—Wheat (red clover); 2—Clover meadow; 3—Flax; 4—Peas; 5—Oats (mammoth clover for fall pasture and green manure).

(e) (Montana) 1—Wheat (red clover); 2—Clover meadow; 3—Potatoes; 4—Barley (mammoth clover for fall pasture and green manure); 5—Oats.

(f) (Montana) 1—Oats (mammoth clover for fall pasture and green manure); 2—Potatoes or sugar beets; 3—Peas; and a fourth field in alfalfa according to the plan of Diagram XVIII.

(g) (Montana) 1—Barley (clover and timothy); 2—Meadow; 3—Pasture; 4—Oats; and a fifth field in alfalfa according to the plan of Diagram XVIII.

(h) (Utah) 1—Sugar beets; 2—Oats and peas for hay; 3—Sugar beets; 4—Oats; and a fifth field in alfalfa according to the plan of Diagram XVIII.

(i) (Utah) 1—Corn; 2—Sugar beets; 3—Peas for hay; 4—Oats; and a fifth field in alfalfa according to the plan of Diagram XVIII.

(j) (Utah) 1—Sugar beets (winter vetch); 2—Vetch crop plowed under, sugar beets or potatoes; 3—Barley; and a fourth field in alfalfa according to the plan of Diagram XVIII.

(k) (Utah) 1—Oats; 2—Peas; 3—Corn or potatoes; 4—Barley; and a fifth field in alfalfa according to the plan of Diagram XVIII.

(l) (Oregon) 1—Sugar beets (winter vetch); 2—Vetch crop plowed under, sugar beets or potatoes; 3—Barley; and a fourth field in alfalfa according to the plan of Diagram XVIII.

(m) (Oregon) 1—Barley (mammoth clover for pasture and green manure); 2—Potatoes; 3—Oats; 4—Wheat; and a fifth field in alfalfa according to the plan of Diagram XVIII.

(n) (Idaho) 1—Wheat; 2—Wheat (mammoth clover for pasture and green manure); 3—Oats; 4—Barley; and a fifth field in alfalfa according to the plan of Diagram XVIII.

(o) (Idaho) 1—Potaotes or sugar beets; 2—Potatoes or sugar beets; 3—Oats or barley; and a fourth field in alfalfa according to the plan of Diagram XVIII.

(p) (Idaho) 1—Potatoes or sugar beets; 2—Oats (mammoth clover for fall pasture and green manure); 3—Potatoes or sugar beets; 4—Wheat, and a fifth field in alfalfa according to the plan of Diagram XVIII.

(q) (Arizona and Nevada) 1—Oats; 2—Barley; 3—Barley; and a fourth field in alfalfa according to the plan of Diagram XVIII.

(r) (New Mexico) 1—Oats; 2—Barley (clover for fall pasture and green manure); 3—Corn; 4—Wheat; and a fifth field in alfalfa according to the plan of Diagram XVIII.

(s) (New Mexico) 1—Barley (clover for pasture and green manure); 2—Potatoes; 3—Oats; and a fourth field in alfalfa as in Diagram XVIII.

(t) (Wyoming) 1—Oats; 2—Peas for pasture; 3—Barley.
(u) (Wyoming) 1—Potatoes or sugar beets; 2—Peas for pasture; 3—Barley; and a fourth field in alfalfa according to the plan of Diagram XVIII.
(v) (Wyoming) 1—Oats; 2—Potatoes; 3—Wheat; and a fourth field in alfalfa as in Diagram XVIII.
(w) (California) 1—Sugar beets (winter vetch); 2—Vetch crop plowed under, sugar beets; 3—Barley; and a fourth field in alfalfa as in Diagram XVIII.
(x) (California) 1—Wheat (winter vetch); 2—Vetch crop plowed under, corn or milo maize; 3—Barley (winter vetch); 4—Vetch crop plowed under, barley; and a fifth field in alfalfa according to the plan of Diagram XVIII.
(y) (Colorado) 1—Oats; 2—Peas; 3—Potatoes or sugar beets; 4—Barley or wheat; and a fifth field in alfalfa according to the plan of Diagram XVIII.
(z) (Colorado) 1—Potatoes or sugar beets; 2—Barley (clover for pasture or green manure); 3—Potatoes or sugar beets; 4—Wheat; and a fifth field in alfalfa according to the plan of Diagram XVIII.

PROBLEMS AND PRACTICUMS

(1) Prepare a table from the United States Census Reports that will show, in the order of their importance, the values produced by the various agricultural enterprises of the Western states. What are some of the important specialized types of agriculture pursued in the Western states?

(2) What are the most important "cash crops" of the Western states? See U. S. Census Reports.

(3) What is the average size of the farms in the Western states? What per cent of the farm land area in these states is under cultivation. See U. S. Census Reports.

(4) Are there any large areas of virgin land remaining in the Western states? If so, where located? What crops and types of farming are best adapted to these new regions? See reports and bulletins U. S. Departments Interior and Agriculture.

(5) Can pork be produced as cheaply and profitably in the Western states without corn as in the corn belt states? Write a short essay on this problem outlining a plan for pork production without corn. Compare costs of production without corn with costs where corn is used for fattening swine. Consider land values, pastures, crops, markets, labor, and methods of feeding. State your conclusions.

(6) Prepare diagrams that will fully illustrate practical rotation plans for the following types of farming in the Western states: Diversified farming producing grain and live stock with rotation pastures, and with permanent or range pastures; intensive dairying on irrigated land with no pasture other than meadow aftermath; dairying and swine production with rotation pastures; specialized swine, sheep and cattle farms; diversified farming on irrigated land with potatoes and peas as cash crops, and the hay and grain fed to sheep, cattle or swine; large grain farm unirrigated land; specialized pea and potato farm irrigated land; specialized sugar beet farm irrigated land; mixed grain and live stock farming on unirrigated land.

(7) Write a short essay on tillage methods for semi-arid regions.

(8) Prepare a diagram that will fully illustrate a rotation plan to include methods for quickly increasing the nitrogen content of a soil naturally weak in nitrogen but rich in phosphorus and potassium.

(9) In what manner may the practice of irrigation injure the fertility of soils?

CHAPTER XII

PRACTICABILITY OF ROTATIONS AND FIELD PLANS

The Chief Criticisms brought against systematic crop rotation as a practical policy in farm management are: (1) that a rigid system of crop rotation does not take into account the exigencies of the seasons, that is to say, crop failures and variations in climate that would interrupt a regular systematic scheme of cropping, and (2) that a rigid scheme of cropping does not permit the farm proprietor to alter his business in accord with the periodic changes in market demands.

These criticisms are not of a serious nature and do not offer any insurmountable obstacles in the practice of systematic crop rotation. It is true that unfavorable and unusual climatic factors may interrupt a regular, projected plan of cropping. For example, a field of timothy and clover is sown in the North Central or North Atlantic states to provide meadow grass for one year and pasture grass for two succeeding years. A severe winter or an unforeseen period of drouth may injure the stand of grass so sown, and at first glance it would seem as though the rotation had been completely interrupted. If hardy grasses, as timothy or brome grass, are sown in a mixture with clover, total loss of the crop rarely occurs; but, in case the stand is very bad, forage, to replace the meadow grass, can be easily provided with thickly sown fodder corn, oat hay, pea hay, vetch hay, or other annual forage crop. Then, if the rotation plan called for two years of pasture land following the meadow,

another seeding of clover and timothy could be made with the annual forage crop, and thus the original rotation plan would soon be reinstated.

In short course rotations where it is not planned to leave the land seeded down to grass crops for more than one or two years, the loss of a grass crop from freezing out or drouth can be met by growing fodder corn, oats and peas, millet, or other annual forage crops, for cured forage, and pasture can be provided by means of catch crops such as clover, field peas, winter rye, rape, vetch, or other annual crop. The loss of the humus producing function of the clover crop, in cases where fodder corn, oat hay, or millet are substituted for the clover crop of the rotation, can be easily recovered by introducing a green manure crop with the fodder corn or oat hay or with the grain crop of the rotation, and plowing the organic matter under in the late autumn.

The interruption of a regular rotation plan, caused by failure to get a satisfactory stand of grasses and clover, is not as likely to occur in the South Atlantic and South Central groups of states as in the North Central or North Atlantic states, because, generally speaking, the winters are less severe, and, therefore, there is less chance for the plan to be interrupted. There is, moreover, such a wealth of forage and pasture crops to choose from in these regions that substitutions are easily made for regular crops that have failed.

Crop failures in any region of the United States do not form a real obstacle to the practice of crop rotation providing the farm manager is awake to the use of annual forage and pasture crops, and to the use of some green manure crop that will supply humus to the soil in case the regular meadow and pasture crops of his rotation plan have failed.

Crop rotation, also, need not be organized in such a rigid manner as to prevent the farm proprietor from having a

choice of crops that can be altered at will to suit fluctuating markets and his own crop preferences. So long as the grain, grass, and cultivated crops are alternated it makes no great difference whether wheat, barley, flax, oats or rye are grown as the grain crop, or corn, Kafir corn, milo maize, potatoes, sugar beets, or cotton, are grown as the cultivated crop. About the only fixed feature of a systematic crop rotation is the use of nitrogen gathering and humus producing legume crops to be fed to live stock or to be plowed under as a green manure crop, and here also the farm manager has a great variety of useful crops from which to choose. This feature of crop rotation must ever be fixed and permanent, for agriculture, in its broadest sense, cannot be successfully practiced for any length of time without the use of crops that will maintain the humus supplies of the soil, and also make use of atmospheric nitrogen as a source of plant food. Crop rotations may be systematic and yet extremely elastic. A great variety of crops exist in the grain, grass, and cultivated crop classification from which those crops can be selected that best suit the market demands, the local climatic conditions, and the natural inclination of the farmer.

From the viewpoint of soil fertility, the main idea, in planning a rotation of crops, is to plan a scheme of cropping that will maintain the "humus equilibrium" of the soil, that will utilize atmospheric nitrogen to some extent as a source of plant food, and that will keep the soil in good physical condition. From the viewpoint of "business management," the main idea in planning a rotation of crops is to provide a field system that will effect economies in the application of man and horse labor in crop production and that will diffuse the labor of the farm as widely as possible throughout the year. Crop rotation, wisely planned, meets these essential factors in successful farm management, and is by no means

a theory that has to be discarded on account of climatic variations or market fluctuations.

The Value of Field Plans and Maps in Farm Management. Rotation plans and maps are as valuable to the farm proprietor in the management of his affairs as the building plans and specifications of the architect, or the surveys of a railway engineer, in the management of their affairs. Houses can be constructed without plans and specifications, railways can be built without preliminary surveys, and farms can be managed without definite rotation plans; but in each case the work cannot be most successful unless definite and exact plans are developed and maintained. A survey and plat of a farm will often reveal many weaknesses in the scheme of farm management that would never come to the attention of the farm manager unless recorded on paper in such a manner as to graphically display the farm and its enterprises.

Farm plans and maps are very useful in recording yields, dates of manuring and many other facts pertaining to the farm business, as well as to provide the farm manager with a comprehensive plan of the work that is under his guidance and control. No man's memory is sufficiently reliable to carry all the important facts pertaining to his business. A complete record of the fields is an essential factor in good farm management. The use or non-use of good rotation plans and maps in agriculture is the difference between system, foresight, and organization on the one hand, and shiftlessness, guesswork, and haphazard methods on the other. System and organization are most essential factors in business undertakings of any kind, and particularly important in agriculture, with its necessary multiplicity of details.

PROBLEMS AND PRACTICUMS

(1) Prepare a diagram that will fully illustrate the crops and methods that may be employed in making substitutions for injured crops and crop failures in a three-year, five-year, and seven year rotation plan. Use rotation plans and crops adapted to your local conditions.

(2) Prepare a map of your home farm or some farm with which you are familiar, on which dates of manuring, green manuring, fallowing, deep tillage, pasture records, yields and other important data may be easily recorded. A map for this purpose should correspond to a map of the completely planned farm showing fields laid out in the definite rotation plan.

PART III

ROTATION AND COMMERCIAL FERTILIZERS

CHAPTER I

RELATION OF FERTILIZERS TO PERMANENT AGRICULTURE

Comparative Permanency of Agriculture. Comparisons between agriculture and mining, lumbering, manufacturing, or transportation, are often made in the press or on the public platform, in which agriculture is credited with being the corner stone of national prosperity and the one permanent asset of the nation. It is pointed out that coal mines may become exhausted and forests cut down, but that the soil areas are inexhaustible wealth producers from which man may indefinitely produce food as well as fuel and building material long after our mines and forests are exhausted. We are quite accustomed, as a nation, to quiet our apprehensions over abandoned mines, closed sawmills, and the various industries that depend directly or indirectly on these natural resources, with the comforting thought that as a nation we possess immense areas of agricultural lands that are a permanent national asset for the creation of wealth.

It is true, of course, that agriculture is the corner stone of American business. Cotton, corn, wheat, hay, and live stock products are the foundation of American commerce. The production, transportation and manufacture of agricultural products exceed in commercial importance the various mining and allied manufacturing enterprises of the nation.

It is further true that fertile agricultural lands are a greater and more permanent national asset than rich mines or great manufacturing enterprises depending for success on cheap fuel, skilled groups of laborers, and highly organized transportation facilities. In comparison with these industries agriculture is more permanent, less subject to variation, less affected by national competition, and, therefore, highly desirable as a national asset. The nation whose commercial activities are largely built around the products of its own agricultural lands is more certain of its future existence than the nation which is depending largely on mining and manufacturing for existence and which must import agricultural products.

But agriculture, as heretofore practiced, is only a comparatively permanent industry and not absolutely permanent. Nations have achieved wealth and power and risen to a prominent place in history on the basis of agricultural wealth only to recede as their agriculture waned. Agriculture is, by comparison, a more permanent industry than mining, and appears absolutely permanent in the eyes of men whose lives span but a moment in the history of the earth they inhabit, but from the broad viewpoint of national wealth and long periods of time, agriculture, as commonly practiced, is no more a permanent, indestructible industry than mining. Just as the mine contains a certain definite deposit of coal, iron or copper, so the soil contains a certain definite deposit of the mineral materials that constitute plant food, varying in different soils according to the composition of the rock materials from which the soil was derived.

Subtraction of Plant Food. Now, when agriculture is practiced, there is a constant drain on the plant food supplies of the soil. The farmer is continuously at work, while growing crops, on a process which as truly reduces the origi-

nal supplies of plant food in the soil as the miner reduces the total supply of coal in the mine with every ton that is taken out and shipped away. The valuable minerals of the mine and the valuable mineral compounds of the soil were produced and deposited in ages past by geologic processes that are mainly a mystery to man. Man has learned to produce in his laboratories some of the valuable minerals of the mine, and he has learned to create some of the valuable forms of plant food in the soil from elementary matter, but, in the main, man continuously subtracts from Nature's stores of plant food in the soil and from her stores of valuable minerals, and adds but little to the original supply.

It is self-evident in the practice of agriculture, that, if no forms of mineral plant food are ever added to the soil areas on which crops are grown, the original supply provided by nature must eventually decrease to a point where crops cannot be profitably grown. The rate of decrease is, of course, very variable. On soils of high natural fertility, containing an abundance of all the essential forms of plant food, the time required to impoverish the soil would be much longer than on a soil that is naturally deficient in some particular form of plant food, such as phosphorus. Then, too, the rate of decrease varies with methods of agriculture. Subtraction from the original supplies of plant food in the soil is more rapid when grain and hay products are sold away from the land than when they are fed to live stock and the manure returned to the land.

Unavoidable Losses of Plant Food. Crop rotation, green manures, animal manures, and thorough tillage are useful in stimulating soil productivity and in providing checks on the subtraction of certain forms of plant food from the natural supplies of the soil; but these methods are powerless to actually add any form of plant food to the soil except

nitrogen. The judicious use of crop rotations and green manures may actually increase the original supply of nitrogen in the soil by means of legume crops and their parasitic bacteria which gather atmospheric nitrogen; but, with the other essential elements of plant food in the soil, such as phosphorus and potassium, the case is different. Unless these mineral forms of plant food are added to the soil from outside sources, a certain amount of subtraction from the original supply must continually take place under any method of agriculture. The loss may be so gradual as to be almost unnoticeable in the life time of one farming generation, but it is nevertheless going on.

Even with the most careful crop rotation farming, including live stock to consume the products of the soil, and with all animal manures returned directly to the soil, there is a certain gradual loss of phosphorus and potassium in the bones and carcasses of live stock that is sold from the land. Such losses are unavoidable. It is possible to conceive of a scheme of agriculture and the handling of food products and waste products from animal and human bodies wherein the elements of plant food taken from the soil by crops would be almost entirely recovered and returned to the soil, thus balancing the subtraction from the original plant food supplies of the soil. But such a scheme of agriculture is mainly impractical under American conditions of life on account of leaching, soil washing, fermentation of manures, and the waste through city sewers. The practical thing to remember is, that losses of plant food do occur that are unavoidable. With the exception of nitrogen, man has as yet discovered no means for adding to nature's supply of plant food in the soil other than to mine the desired forms of plant food from one region of Mother Earth and transfer the materials to his agricultural soil areas.

Fertility Not Inexhaustible. There is no such thing as soil of inexhaustible fertility. The term can be used relatively, and, from the viewpoint of time as judged by man and his span of life, the term is sufficiently accurate to be justifiable. But from the viewpoint of national life and periods of time that run into hundreds or even thousands of years, there is no such thing as a soil of inexhaustible fertility. If there are any exceptions to this statement, they are to be found in the alluvial soils of such great valleys as the Nile Valley in Africa, and the Rio Grande Valley in North America, where the plant food supplies of the naturally fertile soils are continually being added to by the suspended soil materials brought in by flood or irrigation water. Under such conditions, the term "inexhaustible fertility" may be used with propriety, because natural processes are adding supplies of plant food to the soil to balance any subtractions that may be made through the production of crops. Under the ordinary conditions of agriculture, however, soil of inexhaustible fertility does not truly exist, although agricultural practice which provides crop rotation, animal manures, green manures, cover crops, and thorough tillage, so nearly maintains a balance of the soil's natural supply of plant food as to make the naturally fertile soil appear permanently productive, when judged from the period of time that one man's live occupies.

Ultimate Permanency of Agriculture. With these thoughts in mind, it may be seen that agriculture, as commonly practiced, and as judged from the viewpoint of national life and long periods of time, is no more an absolutely permanent industry than is the mining of mineral-bearing ore. Successful agriculture is dependent on an abundant and available supply of various forms of plant food in the soil, the most important elements of which are nitrogen, phosphorus and

potassium. If any of these necessary forms of plant food become exhausted in the soil through long continued cropping, agriculture becomes unprofitable. In the practice of agriculture we have an absolute control of the nitrogenous plant food of the soil; for, by means of legume crops which assimilate through bacteria the nitrogen of the atmosphere, we can add nitrogen to the soil at will. But, with the other essential elements of plant food, phosphorus and potassium, we have but one method of balancing the eventual loss that must occur in all soils, and that is by adding directly to the soil fertilizing materials that are rich in these forms of plant food.

Agriculture, to be truly permanent for long periods of time, must eventually use some form of fertilizing material that will return to the soil those forms of plant food that have been extracted by crops and totally lost to the soil even under the best kind of farm practice, through the waste of city sewers and the leaching and fermentation of animal manures. When nations take cognizance of these facts about the ultimate permanency of their agriculture, and make provision to check, so far as possible, the fertility waste of city sewers, and to use the various forms of commercial fertilizers, when necessary, to offset the unavoidable losses of phosphorus and potassium that occur in agriculture, then agriculture will become a permanent industry, and bountiful harvests be secured many generations after the pioneer generation which broke the virgin sod and sowed the first crops.

PROBLEMS AND PRACTICUMS

(1) Write a short essay describing as fully as possible the origin of the soils in your community. From what kinds of rock were the soils of your community derived? What were the processes that were at work in past ages to form these soils?

(2) What is meant by a sedentary soil? Alluvial soil? Glacial till soil? See reference books on soils.

(3) What are some of the important plant food characteristics of soils derived from limestone, sandstone, and granite rocks? See reference books on soils.

(4) Why are soils in semi-arid regions commonly very rich in available plant food when first put under the plow? Make comparisons with soils in humid climates.

(5) If a city of 100,000 people consumes 400,000 bushels of wheat annually, how many pounds of nitrogen, phosphorus and potassium are annually taken away from tributary farm lands and entirely lost by the usual American sewer and garbage system? See page 296.

Photo by courtesy "The Farmer."

Liquid manure spreader in operation. Large losses in the fertilizer value of animal manures occur when the urine is allowed to go to waste. By means of stable drains and reservoirs this valuable fertilizer can be conserved, pumped into the spreader tank, and spread on the land.

CHAPTER II

LIMITATIONS OF CROP ROTATION IN THE MAINTENANCE OF PRODUCTIVITY

Insufficiency of Crop Rotation. In considering the value of systematic crop rotation with its pasture and meadow crops, annual catch crop pastures, cover crops, and green manure crops, from the viewpoint of soil fertility, the statement so often used in a popular sense that "crop rotation enriches the land" is incorrect. A liberal use of legume crops in a rotation may actually enrich the land as regards nitrogen, and increase the total supply of this element to an amount even greater than the natural store of nitrogenous matter; but, with the possible exception of nitrogen, crop rotation cannot possibly add plant food to the soil in excess of the supplies provided by nature. As a matter of fact, crop rotation usually results in the removal of more plant food from the soil than continuous cropping to any class of crops, because crop rotation, thorough tillage and an abundance of decaying organic matter in the soil provide those conditions that are essential to the liberation of plant food and the production of maximum crops. If crop rotation were practiced and all the products of the soil sold off the land, the decrease in soil fertility and eventually in productivity would undoubtedly be more rapid and more marked than in case of continuous cropping. Nitrogenous plant food could be maintained by means of green manure legume crops; but, the soil's supply of phosphorus and potassium would surely diminish more rapidly than in continuous cropping.

When crop rotation, however, is combined with live stock pasturing and feeding, and the bulk of the field crop pro-

ducts is fed on the farm, with the animal manures returned to the land, the actual net loss of plant food from the soil is small. Such loss as does occur is represented in the phosphorus and potassium in the bones, hair, and tissue of the live stock products and the losses in the fertilizer value of manure that arise through leaching and fermentation. When the dung and urine of farm animals are as completely saved as possible and returned immediately to the land without barnyard leaching or fermentation, the net loss of plant food from the soil is small, and maximum crops can be produced on naturally fertile soils for long periods of time under such methods of farming.

But, even under the most favorable circumstances, when crop rotation and live stock growing are practiced there is a small loss of phosphorus and potassium continually taking place that is unavoidable. It is incorrect, therefore, to say that "crop rotation enriches the land," for it cannot do this. It can increase the total supply of nitrogenous plant food in the soil and very nearly maintain a balance between the phosphorus and potassium outgo and income, but it cannot add anything to the original supplies of phosphorus and potassium in the soil. As regards soil productivity, the real value of crop rotation, green manures, live stock manures, and thorough tillage, is to keep the soil in good physical condition, maintain or add to the humus and nitrogen supply, to assist those chemical processes in the soil whereby the mineral plant food is made soluble and available to crops, and, when the crops are fed to live stock, to provide a means for returning to the soil the greater part of the plant food taken up by crops.

Crop rotation and green manures stimulate the soil to greater productiveness wherever the soil is well supplied with the various forms of plant food. These practices, how-

ever, cannot make available to crops what does not exist in the soil. If the soil is naturally deficient in some form of plant food, such as phosphorus, for example, and if long continued cropping has reduced the original supply of phosphorus to an amount insufficient for profitable crop production, crop rotation, green manures, and live stock manures, are impotent to add phosphorus to the soil. The only way to increase the plant food supplies of the soil, other than nitrogen, is to directly add fertilizing materials that contain the desired form of plant food.

Sufficiency of Crop Rotation. On naturally fertile soil areas, composed of mixed rock materials, and not naturally deficient in either phosphorus or potassium, and where "soil robbing" agriculture has not been practiced until the soil has become very deficient in phosphorus or potassium, the practicing of crop rotation, including live stock and green manures, provides a system of farming that might be called quasi-permanent, if not absolutely permanent. Under such conditions, agriculture in the United States would rest on a far more permanent basis than hitherto, and many of our best agricultural areas that first came under cultivation since 1880 would avoid for many years the impoverished soil conditions of parts of the North Atlantic and South Atlantic states. The nitrogen and humus supply of the soil would be undiminished, and, while phosphorus and potassium would diminish to some extent, the loss would be much slower than under a system of continuous cropping when all products are sold away from the land.

American agriculture, on the whole, is so young, and so many of our soil areas are so plentifully supplied with the essential elements of plant food, that systems of farming which include crop rotation, annual catch crop pastures, green manures, live stock, and thorough tillage, and which

prevent rapid subtraction from nature's stores of plant food, are the ones most needed to give immediate stability to the agriculture of the United States. If the millions of acres of virgin lands in the Western, North Central, and South Central states that were put under cultivation in this generation of men could be cropped from now on by these methods that are a part of, or associated with, crop rotation, they would most certainly remain productive much longer than if cropped continuously to wheat, corn or cotton.

Undoubtedly, in the generations to come, some of these soil areas will show deficiencies in plant food, particularly phosphorus, that will need correction by means of commercial fertilizers, for it is practically impossible to plan a system of cropping that will not eventually reduce the phosphorus plant food of the soil. But, so long as our surface soils to a depth of twelve to eighteen inches contain an abundant reserve supply of the necessary forms of plant food in such chemical compounds as are mainly unavailable to crop roots, there is no use anticipating the soil deficiencies of the generations to come. We know that a plentiful supply of humus in the soil, provided by crop rotation and green manures, will assist those chemical changes in the soil that gradually place plant food in available forms, and as needed by the crops.

Here are practical means at hand to maintain the productivity of American soils. They cannot actually enrich the land, except in the case of nitrogenous plant food, nor make agriculture absolutely permanent; but they will maintain the productivity of land much longer than continuous cropping, shallow plowing, and non-use of live stock or green manures. There is no use to anticipate the ultimate deficiencies of plant food. Where a deficiency exists, it should be corrected with the addition of fertilizing materials; but

where no marked deficiency as yet exists, the system of cropping provided by crop rotation, live stock, green manures, and thorough tillage, is the practical method to employ in keeping soils in a high state of productivity.

PROBLEMS AND PRACTICUMS

(1) A farm of 160 acres is divided into four fields of 35 acres each, with 20 acres in the farmstead and paddocks. A four-course rotation of corn, oats, clover, and potatoes, is practiced on the four fields. The average yields are: corn, 60 bu. per acre; oats, 50 bu. per acre; clover, 1st cutting, 2 tons per acre, 2nd cutting, 1 ton per acre; potatoes, 150 bu. per acre. If all the products of these fields are sold, how many pounds of nitrogen are annually sold away from the farm? What is the nitrogen loss, if the second crop of clover is plowed under? What is the loss or gain of nitrogen if the potatoes are sold; the second crop of clover plowed under; and the balance of the crop products fed to cattle and the manure returned to the land? See pages 296, 297.

(2) How many pounds of nitrogen are removed from an acre of land by a 50 bu. per acre corn crop and a 50 bu. per acre oat crop (total amount two crops)? If mammoth clover is sown with the oats and plowed under in preparation for corn every alternate year, what is the loss or gain of nitrogen in the two-year period? (Estimate 1½ tons per acre of cured clover to plow under.) See pages 296, 297.

CHAPTER III

NEED FOR COMMERCIAL FERTILIZERS

General Conditions Necessitating the Use of Commercial Fertilizers. In special crop farming with tree, vine, garden or special field crops, where the gross income is high per acre of crop, the feeding and forcing of crops with excess supplies of available plant food, provided in commercial fertilizers, is quite often profitable irrespective of the natural fertility of the soil. The high gross income per acre that can be derived from such crops makes profitable an investment in fertilizers that would be unprofitable with general field crops having less value per acre. With these crops a small percentage of crop increase due to the fertilizers will pay for the fertilizers several times; whereas, in the case of general field crops the same percentage of increase due to the use of fertilizers might not half pay for the fertilizers and thus cause actual loss.

Under general farm and field conditions with staple field crops, it is neither practical nor profitable to purchase commercial fertilizers until experience shows that crop rotation, green manure crops, farm manures, and thorough tillage, are impotent to produce good crops. Before the individual farmer resorts to the use and expense of fertilizers he should be positive that he has done everything possible to keep his soil in good physical condition, to provide conditions for the liberation of plant food within the soil, and to make use of farm manures as a check to the loss of plant food from his farm. When all these practices are positively known to fail in the production of good crops, then it is time to consider the purchase of commercial fertilizers to correct some plant

food deficiency in the soil that can be corrected in no other way than through the direct addition of plant food. Even then, however, the advice of the soil expert should be sought before the farmer should invest much money in commercial fertilizers. The indiscriminate, unscientific use of commercial fertilizers is the cause of great waste, and may be just as influential as a cause of unprofitable farming as failure to use a commercial fertilizer on a soil that is greatly deficient in some form of plant food.

A tendency exists in many of the older farming regions of the United States to resort to an extensive and indiscriminate use of readily available forms of plant food in commercial fertilizers, when a thorough study of the soil and the conditions of farming reveals the fact that there is a greater need for crop rotation, green manures, farm manures, and thorough tillage, than for the commercial fertilizers. The following excerpt from bulletin 160 of the Mississippi Agricultural Experiment Station is a very good statement of this tendency among many farmers to resort to an extensive use of commercial fertilizers without first giving due consideration to other means for keeping soil productive. "The fact is, people have gone fertilizer mad, as it were, and have learned to depend almost entirely on buying plant food in a sack rather than on manufacturing the same on the farm by growing leguminous crops and by keeping more live stock from which to make manure." A statement of this sort does not mean that legume crops and farm manures are all sufficient on all soils to keep them fertile and productive, but that these simple, cheap methods are too often neglected for the lure of the commercial fertilizer.

At the present time there are many soil areas in the North Atlantic, South Atlantic and South Central states, receiving heavy applications of commercial fertilizers, that

would respond greatly to judicious crop rotation, thorough tillage, animal manures, and green manure legume crops, and where the intelligent use of such practices would greatly reduce the farmer's annual bill for fertilizers. The reading of advertisements regarding the efficiency of fertilizers, or the observation that the application of fertilizers brings better crops, leads to the purchase and application of fertilizers without the farmer's realizing that many benefits he secures from them can be secured at less cost by crop rotation, animal manures, green manure legume crops, and thorough tillage. There is a limit to the efficiency of these methods for maintaining soil productivity; but thousands of farmers resort to the indiscriminate use of commercial fertilizers before they have given crop rotation methods a fair trial.

The many demonstration farms of the United States Department of Agriculture in the South Central states have furnished ample proof of the present day need for better tillage and nitrogen and humus producing crops on the old soil areas of these states, and that an increase of soil humus, together with an improved physical condition of the soil, is as essential to successful agriculture as the commercial fertilizer.

The author recollects an experiment that he made on a piece of land in Manchuria that had been cultivated about one hundred years with a continued succession of cultivated crops, such as sorghum and proso millet, and also wheat, barley and soy beans sown in rows and inter-tilled. Yields had been reduced to a very low level, although the native farmers occasionally applied animal manures to the land. The system of farming, however, was such as to rapidly oxidize all organic matter in the soil and to make no provisions for maintaining the "humus equilibrium." The

soil was very apparently deficient in humus and was in a poor physical condition with a plow hardpan under the surface soil. To remedy these very apparent defects a crop of barley was sown on the field and after barley harvest one half of the field was shallow plowed (4 inches) and a cro of soy beans sown. Early in October when the soy bean vines were about eighteen inches high and just starting to pod, the crop was plowed under to a depth of seven to eight inches. The barley stubble on the other half of the field was also plowed at this time to the same depth. The following year Indian corn was planted on both fields. From the time the plants broke through the soil until harvest there was a remarkable difference noticeable in the crops. The crop on the green manured land at all times had a healthier, deeper green color, and the plants were larger, stockier, and broader leaved. At harvest the green manured field yielded about sixty-two bushels per acre and the other field about twenty-five bushels per acre.

This very simple little experiment has been quoted merely to show that there are soil conditions causing unprofitable crops that are easily corrected without the use of commercial fertilizers. In fact, in this case, a heavy application of a complete fertilizer would undoubtedly have been less efficient than the green manure crop and the relatively deep plowing. There are many soil areas in the older parts of the United States, also, where agricultural methods of a similar nature that will improve the physical texture of the soil, liberate latent plant food and fix atmospheric nitrogen in the soil, are more needed than commercial fertilizers.

The commercial fertilizer undoubtedly has its place in the agriculture of many of the older soil areas of the United States to correct the natural or man made plant food deficiencies that cannot be corrected by means of legume crops,

farm manures, thorough tillage and crop rotation. But, nevertheless, the commercial fertilizer cannot take the place of those methods of farming that are a part of, or associated with, proper crop rotation. In fact the real efficiency of the commercial fertilizer is dependent on crop rotation and the farm practices associated with it. Without a good physical condition and an abundant supply of humus in the soil, the commercial fertilizer is relatively unproductive of good results. Its efficiency depends to a large extent on those soil conditions that are best provided by crop rotation, green manure legume crops, farm manures and thorough tillage.

For the general conditions of staple field crop agriculture the only real justification for the purchase and use of commercial fertilizers is an actual or anticipated deficiency in the total supply of phosphorus or potassium plant food in the soil area available to crop roots. The purchase of nitrogen plant food in general farm practice, and for our staple field crops, is usually folly; for it is known that an unlimited supply of nitrogen is in the atmosphere and may be made available at will through legume crops and their parasitic bacteria. Crops remove such comparatively small amounts of iron, chlorine, sulphur, etc., that, for all practical purposes, the soil is inexhaustibly supplied with these forms of plant food. But, when the methods of agriculture have been such as to reduce the supplies of phosphorus and potassium in the soil to a point that makes crop production unprofitable, even where crop rotation, green manures, feeding crops to live stock, and thorough tillage are practiced, then the need for the commercial fertilizer to supply these deficiencies is imperative.

How to Determine the Need for Commercial Fertilizers. Crops in their growth often show indications of plant food deficiencies in the soil. A dull green or yellowish tinge in

the leaves and growing tissues of crops is usually an indication of a deficiency of available nitrogen in the soil, unless drouth or an excessive amount of soil moisture have caused this condition. When clover and alfalfa fail to yield abundantly on old soils where these crops have been sown often before and where it is, therefore, known that the soil is well inoculated with bacteria, it will usually be found that the light yield is due to a deficiency of phosphorus and lime in the soil. This inference is quite often the answer to the complaints of farmers in the older agricultural regions of the Middle West that their clover meadows are not as productive now as they were ten or twenty years ago. The difficulty of securing high grade in wheat grown on old soils, as compared with wheat grown on virgin soil, is usually due to a deficiency of available phosphorus. This is true except where an epidemic of rust or a period of summer drouth is responsible for the poor grade of the grain.

Crop conditions, however, are not sufficiently accurate as an index to conditions of soil fertility and cannot be relied on in determining the plant food deficiencies of a given soil or the best methods to use in correcting them. When crops indicate plant food deficiencies and yields are falling to an unsatisfactory level, the expert soil chemist is the physician to consult for a diagnosis of the conditions. A reliable chemist's soil analysis will reveal the total amounts of the various forms of plant food within the tillable areas of the soil, and also reveal the approximate percentage of total plant food in available condition for crop roots. An analysis of this sort gives a basis for determining the best methods to employ in correcting plant food deficiencies in the soil, although in many cases the analysis should be supplemented with small field tests to definitely prove the profitableness of the proposed methods of soil amendment.

If such an analysis or field test reveals a deficiency in nitrogen below the amount necessary for profitable crop production, the deficiency may be quickly and easily corrected by plowing under legume crops which have gathered nitrogen from the atmosphere. If the analysis reveals the fact that the total supplies of nitrogen, phosphorus, and potassium in the soil are abundant for good crop growth, but that the available supply of any one or all of these elements is low, the remedy is to introduce a system of farming which includes crop rotation, live stock, green manure crops, and thorough tillage, that will cause a continuous process of plant food liberation in the soil, and that will return much of the plant food to the soil where crops may use it again. If the analysis, however, reveals a deficiency in the total supply of either phosphorus or potassium so great as to be below the amounts known to be necessary for profitable crop growth, the use of a commercial fertilizer to correct this deficiency is imperative; for crop rotation, green manures, and live stock cannot possibly correct this plant food deficiency.

The Profitableness of Commercial Fertilizers, then, can be ascertained with approximate correctness by means of the soil chemist's analysis, supplemented by small field trials, when the chemist considers such trials necessary. Every soil area should be studied by itself. The plant food supplies or deficiencies of one state are not applicable to the whole area of the United States. The composition of soil is very variable, and great differences exist in the different parts of a state, county, township, section, or the subdivisions of a section of land. Every farm presents a problem of its own in the maintenance and control of soil fertility and a commercial fertilizer that would be profitable on one farm might have much less value on another farm in the same neighborhood. Before any farmer applies commercial

fertilizers, he should take the precaution to have his soil analyzed by his state or district experiment station, and then use this analysis as a basis for the use of commercial fertilizers, if necessary, or for the planning of methods to correct the plant food deficiencies of his particular soil. In many cases it is wise to try out the proposed plan of soil amendment on strips of land in the farm fields before entering into the purchase of large quantities of commercial fertilizers. The soil chemist's analysis is a guide to the soil's needs, but not an infallible rule. When accompanied by a careful field trial the profitableness of the commercial fertilizer is ascertained with sufficient accuracy.

PROBLEMS AND PRACTICUMS

(1) In normal crop years it is known that a certain field will produce a 20 bu. per acre crop of wheat, or a 150 bu. per acre crop of potatoes. If \$5.00 worth of commercial fertilizers, containing available plant food, is applied to an acre of this land, what per cent of crop increase must be had with the wheat and potatoes to cover fertilizer costs and yield a 10% profit on the money invested in fertilizers, when wheat is worth 80 cents per bushel and potatoes 40 cents per bushel? Which crop would you think most likely to produce the necessary increase?

(2) The cost of producing an acre of wheat is approximately \$9.00; potatoes, \$25.00. If \$5.00 per acre is added to the production costs for fertilizers, and a 20% crop increase is thereby secured in both crops, what is the effect on the net profits?

(3) Ascertain the facilities which your State, County, or Congressional District provides for analyzing fertilizers and soils for farmers. Find out the sources of expert advice in these matters.

(4) How would you proceed to secure a representative sample of surface soil and subsoil from a field?

(5) Individual students, or small groups of students, should collect a soil sample, submit it to the proper experts for analysis, and then carry out on a small strip of land such fertilizer recommendations as are made. Tabulate the costs and increase of crop over yields on an adjoining plot receiving no fertilizers.

CHAPTER IV

PHOSPHORUS, THE KEY TO PERMANENT PRODUCTIVITY

Dearth of Phosphorus. Analyses of agricultural soils all over the United States reveal the general fact that phosphorus is the element of plant food most commonly deficient, or, if not naturally deficient, the element of plant food most likely to become deficient. Potassium is commonly so abundant in soils that for the great majority of soil areas the supply is practically inexhaustible, especially if good farming is practiced, with live stock to check the subtractions from the original supplies in the soil. Potassium is an element of plant food that is usually deficient in the black, peaty soil areas of old swamp lands, and that must be added to the soil in a commercial fertilizer to secure maximum crop yields. But the soil areas of this nature are comparatively small in the United States, and, on the majority of soils where general farming is practiced, there is an abundance of potassium plant food, and the danger of a widespread potassium deficiency is very remote. The natural supply of nitrogen is small in many of the Western soils; but a nitrogen deficiency is of no great consequence in a consideration of a permanent system of agriculture, because nitrogen is easily controlled by means of legume crops which gather atmospheric nitrogen.

Generally speaking, the Western soil areas are naturally rich in phosphorus in the form of calcium phosphate, plentifully supplied with compounds containing potassium, and somewhat low in their total supply of nitrogen. Plant food is usually readily available in the Western soil, and at the present time the necessity is not felt for methods of agriculture that will release available forms of plant food from the

more stable chemical compounds of the soil. As agriculture ages in this region, phosphorus will eventually be the element of plant food requiring most consideration, although nitrogen maintenance will need prior attention.

Geographical Variations. In the North Central states the majority of the agricultural soil areas were naturally blessed with a well balanced store of the essential elements of plant food. This is particularly true of the upper regions of the Mississippi Valley where glacial activity produced soils of mixed materials. In this region the extensive and continuous growth of corn, wheat, oats and other small grains for the past generation, the bulk of which crops has been exported from the land with consequent loss of plant food from the soil, has been slowly creating a phosphorus deficiency. This deficiency has not become very noticeable as yet in the newer states in the northern part of this region, but, in the southern part, where agriculture is older, phosphorus deficiency has already become a soil problem of considerable importance. The soils of this region are so universally rich in potassium that the danger of a potassium deficiency is extremely remote, and, whenever nitrogen deficiencies occur, the method for correction is always at hand in the legume crop.

With occasional differences these same general facts about plant food deficiencies in the soil are applicable to the North Atlantic, South Atlantic and South Central states. Occasionally there is a deficiency in potassium, but, generally speaking, potassium is abundant in these soils, and a serious potassium deficiency is very remote. Lime deficiencies in soils, or soil acidity, are found more often, perhaps, in these regions than in the North Central or Western states, and the liming of soil to correct them is, therefore, not uncommon. But nearly everywhere they are of minor importance as

compared with present day or anticipated phosphorus deficiencies. In many of the older agricultural regions of the North Atlantic, South Atlantic, or South Central states, the natural store of phosphorus compounds in the soil was relatively small, and thus, when agriculture was practiced for several generations with no special consideration for phosphorus plant food, a genuine phosphorus deficiency has arisen. In other places the phosphorus deficiency is an anticipated soil condition that will confront the farmers before many years.

Importance. Considering these general facts, therefore, that are proven by studies and analyses all over the United States, it may be seen that, on the great majority of soils where staple field crops are being grown, phosphorus is the element of plant food most likely to become deficient and to necessitate the use of a commercial fertilizer. Maintaining an abundant supply of phosphorus plant food in the soil is undoubtedly the key to soil productivity for the vast majority of the soil areas of the United States. Thus the problem of using commercial fertilizers in general field crop agriculture, whenever necessary, to the best advantage, is mainly a problem of securing cheap phosphorus and applying it to the soil by such methods as will bring the greatest benefits.

PROBLEMS AND PRACTICUMS

(1) From your State Agricultural Experiment Station secure all soil survey maps and soil analysis reports that soil experts have made in your home state. Study these maps and analyses carefully to learn about the origin of the soils, the natural supplies of plant food in the soil, the natural deficiencies of the soils, if any, and what amendments are necessary, if any, to secure maximum productiveness on the various soil areas. Also secure publications of Experiment Station and co-operative fertilizer tests on the soils of your region and study the results secured.

CHAPTER V

SOURCE AND VALUE OF COMMERCIAL FERTILIZERS

Analyses and Costs. Before the farmer buys and uses commercial fertilizers for the correction of phosphorus or other plant food deficiency in the soil, he should know something about the sources of commercial fertilizers, the amounts of essential plant food elements which they contain, the availability of this plant food to crops, the comparative cost per ton of the fertilizer, and the comparative cost per pound of the essential elements of plant food contained in the fertilizer. With these facts before him, as well as knowledge of the plant food deficiencies of his soil as revealed through a reliable soil analysis or a small field test, he can plan to correct these soil deficiencies at the minimum of cost and with consideration for maximum results. Without these facts before him, the use of commercial fertilizers is mere guesswork and not likely to result in the desired combination of maximum results at the minimum of cost.

In the accompanying table these various facts about commercial fertilizers are summarized in such a manner as to make easy the comparison of one form of fertilizer material with another. For the purpose of this table only those kinds of fertilizing material are displayed that are quite abundant in the markets of the United States. Prices are shown at various large distributing centers.

Table I—Useful Facts about Standard Commercial Fertilizers.

Kinds of Fertilizer	Analyses			Plant Food Immediately Available To Crops or Not	Average Retail Cost Per Ton						
	Nitrogen Pounds in 1 Ton	Phosphorus Pounds in 1 Ton	Potassium Pounds in 1 Ton		Boston, Mass. Territory	Charleston, S. C. Territory	St. Louis, Mo. Territory	Chicago, Ill. Territory	St. Paul, Minn. Territory	San Francisco, Cal. Territory	Los Angeles, Cal. Territory
					Dollars	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
High Grade Phosphate Rock	....	240–320	....	No	7.50 8.50	5.00 6.00	6.00 7.00	7.00 8.00	8.50 10.00	7.50 9.00	7.50 9.00
Low Grade Phosphate Rock	....	100–240	....	No	6.50 7.50	4.00 5.00	5.00 6.00	6.00 7.00	7.50 8.50	......	......
Acid Phosphate	....	131–157	....	Yes	14.60	9.50	18.00	18.00	20.00	16.00	16.00
Ground Bone Steamed	20–80	175–254	....	No	31.60	......	26.00	28.00	25.00	25.00	25.00
Thomas Slag Phosphate	....	140	....	No	......	......	......	......	......	18.00	18.00
Sulphate of Potash	....	....	432–797	Yes	49.85	45.50	53.00	50.00	55.00	55.00	55.00
Muriate of Potash	....	....	830	Yes	42.10	35.50	46.00	45.00	50.00	47.50	47.50
Kainit	....	....	191–217	Yes	15.00	9.25	......	16.00	......	18.00	18.00
Wood Ashes	....	9–36	50–149	Yes	12.00	......	......	......	......	......	......
Dried Blood	200–260	4–13	10–13	Yes	51.50	52.80	60.00	60.00	60.00	55.00	55.00
Tankage	80–240	62–175	....	No	32.65	34.50	......	30.00	30.00	35.00	35.00
Sulphate of Ammonia	400–410	....	....	Yes	73.00	68.00	......	......	......	75.00	75.00
Nitrate of Soda	300–320	....	....	Yes	56.75	52.50	60.00	60.00	65.00	47.50	47.50
Average Manufactured Complete Fertilizer	20–100	17–87	17–166	Yes	33.00	30.00	......	30.00	28.00	37.50	37.50

NOTE: The analyses and prices given in this table were furnished by courtesy of the following firms and Agricultural Experiment Stations: American Agricultural Chemical Company, Boston, Massachusetts; Farmers' Ground Rock Phosphate Company, Mount Pleasant, Tennessee; Central Kentucky Phosphate Company, Lexington, Kentucky; Natural Phosphate Company, Nashville, Tennessee; Swift and Company, South Saint Paul, Minnesota; Pacific Bone, Coal and Fertilizing Company, San Francisco, California; Bradley Brothers, Sage, Wyoming; San Francisco Chemical Company, Montpelier, Idaho; and the Agricultural Experiment Stations of the States of Illinois, Massachusetts, South Carolina, Missouri, and California.

The prices shown for Western phosphate rock are approximations only, as there is practically no demand as yet in the Western states for ground phosphate rock. Such rock as is mined is shipped to Pacific coast points for use in manufacturing acid phosphate to be sold in the fruit and truck growing districts. The freight charges on phosphate rock in car lots will amount to $2.50 to $4.25 per ton from the Western mines to the various important agricultural districts of the Western states. The cost of grinding averages about 75 cents per ton. It may be estimated, therefore, that phosphate rock can be delivered for $6.00 to $9.00 per ton at all important agricultural centers of the West, whenever it becomes apparent that there is a need for phosphate fertilizers in Western agriculture.

The analyses shown in this table give the pounds of the elements, nitrogen, phosphorus, and potassium in one ton of fertilizing material. The terms used by manufacturers and chemists to describe fertilizer analyses are not always similar and are, therefore, likely to be confusing. It is usually customary to guarantee nitrogen on the basis of the per cent of the element nitrogen in the fertilizer material and not on the basis of any compounds containing this element, but a number of confusing terms are in use relative to phosphorus and potassium plant food. Sometimes fertilizers are guaranteed for calcium phosphate, at other times for phosphoric acid, and again for phosphorus. The simplest analysis would be on the basis of the element phosphorus, as both calcium phosphate and phosphoric acid are chemical compounds only a portion of which is actual phosphorus valuable for plant food. Any of these terms pertaining to phosphorus may be reduced to a common denominator by the following rules: calcium phosphate contains 45.8% of phosphoric acid and 20% of phosphorus; and phosphoric acid con-

tains 43⅔% of the element phosphorus. Fertilizer analyses commonly give the amount of potassium in terms of potash—a compound containing potassium. The amount of actual potassium in potash may be calculated by multiplying the potash analysis by .83. If an analysis of nitrogen is given in terms of ammonia it may be reduced to the nitrogen equivalent by multiplying the ammonia analysis by .823.

Commercial fertilizers are sold on the basis of a definite guarantee for the percentage amounts of nitrogen, phosphorus or phosphoric acid, and potash which they contain. Price, therefore, varies to a large extent according to the analysis. For example: if ground phosphate rock analyzing 14% phosphorus is worth $4.00 per ton at the mines, rock analyzing 10% phosphorus would be worth only $2.85 per ton. State laws and inspection protect the purchaser from willful fraud in fertilizer analyses and provide for sale of fertilizers under analyses guaranteed by the manufacturer. In the purchase of large quantities of commercial fertilizers it is usually wise to collect a representative sample of the material and submit it for analysis to the State officer authorized by law to inspect and analyze the fertilizers offered for sale in the territory under his jurisdiction. By so doing the purchaser may satisfy himself that neither error nor misrepresentation has prevented him from getting full value for his investment.

In studying the comparative value of fertilizers there are three important factors to be considered by the purchaser, (1) the plant food deficiency of the soil needing amendment, (2) the use of the fertilizer for the immediate or future needs of crops and a consideration, therefore, of whether the fertilizer contains plant food in a readily available form or not, and (3) the cost per pound of the element of plant food it is desired to use in correcting the soil's deficiencies.

The fertilizers shown in this table have been roughly divided into two groups on the basis of their availability to crops. Thus in the column headed "Plant Food Immediately Available to Crops or Not" the word "yes" is used for those fertilizers that may be applied to the land just prior to crop planting and which contain the elements of plant food in readily soluble compounds that can be immediately absorbed by the roots of growing crops. In the same manner the word "no" is used to designate fertilizers which contain elements of plant food in compounds not soluble in water but in compounds that must be broken down through chemical change and reaction before the elements of plant food can be absorbed by the roots of crops.

The price per ton is not the final index of value in a fertilizer, but rather the cost per pound of the desired elements of plant food, considered in connection with the needs of the soil and the necessity or non-necessity for a fertilizer that contains immediately available forms of plant food. For the purposes of illustration let us compare the cost per pound of phosphorus and potassium in various fertilizing materials, based on the market prices for fertilizers in Chicago territory as shown in this table.

The cost of phosphorus in phosphate rock analyzing 13% phosphorus, and costing $7.50 per ton, is 2.9 cents per pound; in acid phosphate analyzing 7½% phosphorus, and costing $18.00 per ton, 12 cents per pound; in ground bone steamed analyzing 5 per cent phosphorus, and costing $30.00 per ton, 30 cents per pound; and in an average "complete fertilizer" containing 2% nitrogen, 4% phosphorus, and 2% potash, and costing $30.00 per ton, 37½ cents per pound.

The cost of potassium in muriate of potash analyzing 50% potash, and costing $45.00 per ton, is 5.4 cents per pound; in sulphate of potash analyzing 48% potash, and costing $50.00 per ton, 6.1 cents per pound; in kainit analyzing 12% potash, and costing $16.00 per ton, 8 cents per pound; in a complete fertilizer analyzing 2% potash, and costing $30.00 per ton, 90 cents per pound; and in a complete fertilizer analyzing 10% potash, and costing $35.00 per ton, 21.1 cents per pound.

In the following paragraphs a brief summary of facts is given about the source, availability and use of the various kinds of standard commercial fertilizers.

Phosphate Rock. Great deposits exist in the Southern states, North Carolina, South Carolina, Tennessee, Kentucky, Florida, and Virginia, that contain anywhere from 30% to 70% of the compound calcium phosphate, or the equivalent of 6% to 14% of the element phosphorus. These phosphate rock deposits of the South are the chief source of the world's supply of phosphorus plant food availabie for soil amendment. Large exports of this rock are made to Europe and large amounts are also used in the United States. Phosphate rock deposits also exist in the Western states, Wyoming, Utah, Idaho, and Montana, and, while

little mining has as yet been done, the store of valuable plant food is there awaiting the day when the Western soils will need additions of phosphorus.

The texture and composition of phosphate rock is by no means uniform. There are hard and soft rocks, rocks that are comparatively free from impurities, and other rocks that contain a large percentage of impurities. Thus the terms "high grade" and "low grade" phosphate rock are used to designate the comparative pureness of the rock as regards calcium phosphate, and as regards its freedom from impurities.

The term "raw phosphates" is often used to designate crushed phosphate rock just as it is taken from the mines and used as a fertilizer. In this form the phosphorus contained in the material is locked up in compounds that are unavailable to crop roots, and the phosphorus so added to soil is temporarily inert. In the presence of decaying organic matter in the soil, however, the compounds of raw phosphate rock containing phosphorus will gradually undergo change until, in the course of a few years, the phosphorus will be found in soluble compounds available to crop roots.

Phosphate rock, crushed, is a valuable source of phosphorus to use in amending phosphorus deficiency, provided the deficiency is anticipated by several years, and the soil is abundantly supplied with organic matter to promote chemical changes that will make the phosphorus available to crops. Phosphate rock is a fertilizing material that has no value to the truck farmer, or the grower of a special crop, who wants quick action from a fertilizer. It is a cheap source of phosphorus to be used in connection with general farming as an amendment to a phosphorus deficiency in the soil. An application of 500 to 600 pounds of pulverized phosphate rock per acre every three years in a three-course rotation,

or 800 to 1,000 pounds per acre every five years in a five-course rotation will provide the soil with a bountiful supply of phosphorus and forestall any soil impoverishment due to a deficiency of phosphorus plant food.

Acid Phosphate. This term is used in the commercial fertilizer trade to designate a material formed by treating pulverized phosphate rock with sulphuric acid. Approximately equal parts of finely ground rock and sulphuric acid are brought together in leaden tanks. A chemical reaction takes place which forms a compound containing about 18% phosphoric acid or about 8% phosphorus that is quite soluble and that is readily available to the roots of crops, whereas the compounds of the rock containing phosphorus are insoluble and unvailable to crop roots prior to treatment.

Acid phosphate goes into solution easily in the soil and may be absorbed at once by growing crops. Large amounts of this readily available form of phosphorus are used to mix with other forms of plant food in the "complete fertilizer" made up for the use of the gardener and the special crop farmer who want a quick acting fertilizer. Acid phosphate is sometimes applied alone to soils that are greatly deficient in phosphorus. It is usually scattered over the soil and harrowed in prior to seeding at the rate of 100 to 400 pounds per acre, depending on the soil and the crop to be grown.

Ground Bone Steamed. The bones of animals contain from 8% to 11% of the element phosphorus. Air dried bones, if crushed and ground fine, make an excellent phosphate fertilizer, the phosphorus being somewhat more readily available to crop roots than the phosphorus compounds of raw phosphate rock. Bones are sometimes subjected to super-heated steam to remove the organic matter, and are then ground fine for fertilizer. Steamed bone meal contains from 10% to 13% of the element phosphorus and is a more

active and available fertilizer than air dried bones, although the phosphorus compounds are not as soluble and readily available to crops as those in "acid phosphate."

Ground bone steamed is a by-product of all meat packing plants that is of considerable importance. It is sometimes sold alone for a phosphate fertilizer and also treated with sulphuric acid and mixed with other materials in the "complete fertilizer." As a phosphate fertilizer, when untreated with sulphuric acid, it would be used in much the same manner as "raw phosphate rock."

Sulphate of Potash is a high grade potash fertilizer prepared for the market chiefly from the crude deposits of various salts at Stassfurt, Germany. A good sample of sulphate of potash will contain from 45% to 50% potash, or 37% to 41% of the element potassium. It is a very concentrated form of potash fertilizer and can be used without danger for all kinds of crops. It is readily available to growing crops. A top-dressing of 150 to 300 pounds per acre on soils known to be deficient in potash will provide available potash for several crops, depending on what crops are grown, root crops, for example, requiring much more potash than grain crops.

Muriate of Potash is a manufactured product sometimes known as potassium chloride. The amount of potash it contains will range from 35% to 60%, the usual market standard being 50% potash, or 41.5% of the element potassium. It is also a concentrated form of potash fertilizer and is readily soluble and available to growing crops. For general garden and farm crops it is a cheap and quick acting potash fertilizer, but experience has shown that it is not the most desirable potash fertilizer for such crops as potatoes, sugar beets, and tobacco. When used in large amounts, it is likely to affect the quality of these crops unfavorably.

Muriate of potash is very extensively used on peaty land deficient in potash, and also on ordinary agricultural lands for grass and grain crops. It is applied in the same manner and amounts as sulphate of potash.

Kainit is a mineral taken from the Stassfurt mines in Germany. It is composed of several chemical compounds among which is potassium sulphate. An average sample of kainit contains about 12% potash, or about 10% of the element potassium. Kainit is one of the cheapest forms of potash fertilizer. It is readily soluble in water and available to growing crops. It is extensively used as a potash fertilizer and also as a source of potash for the complete fertilizer. It must be applied in larger amounts per acre than sulphate of potash or muriate of potash; for it is not as concentrated a form of fertilizer. It would require approximately 800 pounds of kainit, for example, to supply as much potassium as is contained in 200 pounds of muriate of potash.

Wood Ashes contain from 2% to 10% of potash (1.7% to 8.3% of the element potassium), .4% to 2% of phosphorus, and 18% to 50% of lime. Hardwood ashes are much richer in potash and phosphorus than softwood ashes. Wood ashes are commonly regarded as a potash fertilizer only, but ashes from the hard woods contain an appreciable amount of phosphorus as well. When wood ashes have been leached, their fertilizer value is greatly diminished; for the potash and phosphorus compounds are easily soluble in water and are easily leached away. Wood ashes have sufficient value as a fertilizer to make it worth while to conserve them on any farm. The potash and phosphorus which they contain are readily soluble and available to crop roots, and to get the best results the ashes should be spread over land in the spring and harrowed in prior to seeding. A dress-

ing of 150 pounds to 300 pounds per acre is usually sufficient, unless it is known that the soil is greatly deficient in this element of plant food, in which case a larger amount can be profitably used. Wood ashes on the average farm would bring the best results, if applied to root crops such as potatoes, mangels or sugar beets, which draw heavily on potash as a source of plant food.

Dried Blood is a fertilizer by-product of slaughter houses. It is a nitrogen fertilizer and contains very little plant food other than nitrogen. When thoroughly dry, it contains from 6% to 13% of nitrogen. Dried blood ferments quickly in the soil and its nitrogen is quickly made available to growing crops. It is a quick acting nitrogen fertilizer that may be used for truck crops, or on farm lands badly impoverished of nitrogen, where it is desired to quickly provide the soil with available nitrogen.

The nitrogen of dried blood is easily lost by leaching, and, for that reason, it should not be applied to land in large amounts. Two hundred to three hundred pounds per acre is usually sufficient. Dried blood produces best results if it is available to crops in their early stages of growth. For this reason the best time to apply this fertilizer is just prior to seeding, working it into the soil thoroughly with the harrow.

Tankage is also a fertilizer by-product of slaughter houses. It is composed of hide trimmings, hoofs, some blood and some bone. The fat and gelatin of this refuse matter are removed by treatment with super-heated steam, and the remaining refuse, after being dried, is ground and usually mixed with a little slaked lime to prevent rapid fermentation.

Tankage contains from 4% to 12% of nitrogen, and from 3 % to 9% of phosphorus. The nitrogen of tankage is not so readily available to crops as that of dried blood nor the

phosphorus so readily available as the phosphorus in "acid phosphate." Nevertheless, in a moist soil, where chemical change is facilitated, the plant food in tankage is partly available to crops the same season in which it is applied to the land.

Tankage is used mostly by truck gardeners, but has value also as a top-dressing for grass land or a source of phosphorus and nitrogen for badly impoverished plow land. A dressing of 200 to 300 pounds per acre is usually sufficient, and the best method of application is to harrow it into the soil several days before planting time.

Sulphate of Ammonia is a by-product obtained in the manufacture of illuminating gas. It contains about 20% of nitrogen. Sulphate of ammonia is extensively sold as a nitrogen fertilizer. The nitrogen contained in it is readily available to crops. An application of 100 to 200 pounds per acre on impoverished farm lands is sufficient to provide a crop with available nitrogen.

Nitrate of Soda, also known as Chili saltpeter, is mined extensively from natural deposits in Chili and Peru. The chief industry of these two countries, in fact, is the mining and exporting of nitrate of soda. It contains, on the average, about 16% of nitrogen. It is very soluble in water and is the most readily available to crops of all the forms of nitrogen plant food. Because of its solubility, large applications of this fertilizer cannot be profitably made; for those amounts of nitrogen in excess of what the crop takes up are very likely to be leached away. About 150 to 250 pounds per acre is all that can be economically applied without danger of excessive loss from leaching.

Nitrate of soda is used extensively as the nitrogen part of the manufactured "complete fertilizer," and is also used in market gardening to force early growth. Its chief value,

in fact, is as an extremely quick acting nitrogen fertilizer that can be used by the market gardener to force early truck crops.

Average Manufactured Complete Fertilizer. The so-called "complete fertilizer" is a combination of materials containing available forms of nitrogen, phosphorus and potassium, the three most essential elements of plant food. In the manufacturing of the complete fertilizer the proportionate amounts of nitrogen, phosphorus, and potassium, are made to vary according to the soil and crops of the region where sales are contemplated.

The most common materials used for the complete fertilizer are nitrate of soda, to supply nitrogen; acid phosphate, to supply phosphorus; and kainit, to supply potassium. A highly concentrated and available complete fertilizer would be one made of sulphate of ammonia, sulphate of potash, and acid phosphate. A less concentrated, comparatively cheap complete fertilizer, with the plant food somewhat less readily available, could be made from tankage, ground bone steamed and kainit.

The complete fertilizer is manufactured and sold on the theory that most farmers do not thoroughly understand the problems of soil fertility, the amendment of plant food deficiencies in the soil, or the use of raw materials containing plant food which might be used to correct soil deficiencies, and, therefore, a complete fertilizer, pulverized fine, sacked, and guaranteed to contain available forms of all necessary kinds of plant food is the safest and best commercial fertilizer for the average farmer to purchase and use.

Without doubt this theory of the complete fertilizer is correct: otherwise the demand for it would not exist to so great an extent. But, in most cases, the purchase and use of the complete fertilizer is an unnecessary farming expense

that puts more profit in the manufacturer's pocket than in the farmer's. There are conditions in market gardening and occasionally in general farming where the use of the complete fertilizer is warranted; but, generally speaking, the complete fertilizer is an expensive combination of plant food. If a soil is in special need of potassium or phosphorus, for example, the correction of this deficiency is more cheaply made with the special fertilizing material containing the desired plant food than with the complete fertilizer containing several forms of plant food, some of which are not essential to the productivity of this particular soil.

PROBLEMS AND PRACTICUMS

(1) Where are your nearest sources of supply for ground limestone, ground phosphate rock, acid phosphate, potash fertilizers, and packing house by-product fertilizers?

(2) What is the freight rate on a carload of ground limestone from the mines or nearest distributing center to your local railway town? What is the car rate on ground phosphate rock and kainit? What is the rate per cwt. on tankage, ground bone, dried blood, acid phosphate, muriate of potash, sulphate of potash?

(3) If a ton of ground phosphate rock analyzing 16% phosphorus can be purchased at the mines for $4.50 per ton, what is a ton of ground rock worth that analyzes 9% phosphorus?

(4) What is the cost per pound of phosphorus in ground phosphate rock analyzing 14% phosphorus and costing $8.00 per ton delivered? In acid phosphate analyzing 7% phosphorus and costing $18.00 per ton? In ground bone steamed analyzing 10% phosphorus and costing $28.00 per ton? In Thomas Slag Phosphate analyzing 7% phosphorus and costing $18.00 per ton? In tankage analyzing 5% phosphorus and costing $30.00 per ton? In a complete fertilizer analyzing 2% phosphorus and costing $30.00 per ton?

(5) What is the cost per pound of potassium in sulphate of potash analyzing 35% potassium and costing $50.00 per ton? In muriate of potash analyzing 41½% potassium and costing $45.00 per ton? In kainit analyzing 10% potassium and costing

$16.00 per ton? In a complete fertilizer analyzing 3% potassium and costing $30.00 per ton?

(6) What is the cost per pound of nitrogen in dried blood analyzing 12% nitrogen and costing $60.00 per ton? In tankage analyzing 8% nitrogen and costing $30.00 per ton? In nitrate of soda analyzing 15% nitrogen and costing $60.00 per ton? In a complete fertilizer analyzing 2% nitrogen and costing $30.00 per ton?

(7) How many pounds of phosphorus are in a ton of acid phosphate analyzing 16% phosphoric acid? In a ton of ground bone steamed analyzing 47% calcium phosphate? See page 283.

(8) How many pounds of potassium are there in a ton of kainit analyzing 12% potash? In a ton of sulphate of potash analyzing 40% potash? See page 283.

(9) How many pounds of nitrogen in a ton of complete fertilizer analyzing 4% ammonia? See page 283.

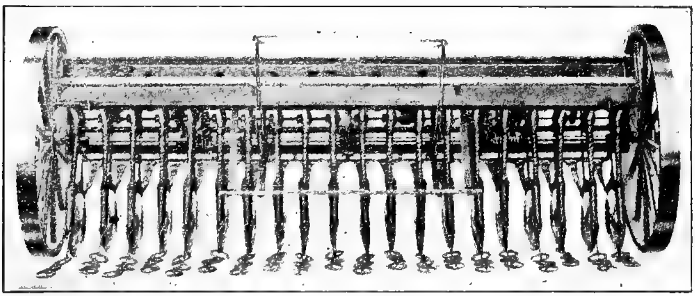


Photo by courtesy Beaver Dam Mfg. Co.

Grain drill with grass seeding attachment. This machine provides the best method for sowing grasses wherever its use is possible.

CHAPTER VI

ECONOMICAL USE OF COMMERCIAL FERTILIZERS

Considering general systems of farming only and the production of such staple field crops as corn, cotton, wheat, oats, barley, flax, potatoes, clover, timothy, and alfalfa, there is no need for the use of commercial fertilizers so long as the reserve supplies of plant food in the soil are abundant and made available to crops by means of crop rotation, green manures, and thorough tillage. The necessity for commercial fertilizers arises only when a naturally fertile soil has been improperly cropped for a long period of time and a deficiency of plant food created, or on a soil in which some important element of plant food is naturally deficient. Commercial fertilizers in general agriculture are mainly needed to amend or correct certain plant food deficiencies in the soil, and, as a rule, their use is actually or comparatively unprofitable, unless they are applied after a careful study of the soil's weaknesses and in such kind and amount as to remedy these weaknesses.

Maximum results with commercial fertilizers at the minimum cost are secured only (1) when the fertilizer used provides the element of plant food most needed by the soil and which is the limiting factor in crop production; (2) when the fertilizer is bought in such form as to give the minimum cost per pound of actual plant food; and (3) when the fertilizer is used in combination with farming methods that keep the soil well supplied with organic matter and in the best possible physical condition. These factors bearing on the profitable use of commercial fertilizers are fully explained in

the following paragraphs as well as the best methods for the application of fertilizers to land.

The Draft of Field Crops on the Important Elements of Plant Food in the Soil. The food requirements of crops are revealed by analyses of plant substance. Corn, for example, just prior to maturity, contains about eighty per cent water and twenty per cent dry matter. In percentage amounts of the original plant substance the dry matter contains about two per cent of nitrogenous organic compounds, such as protein (of which about one sixth is pure nitrogen); about sixteen per cent of non-nitrogenous organic compounds, such as starch, sugar, and fiber; and about two per cent of ash, or mineral matter, that remains when the dry matter is burned.

The non-nitrogenous organic compounds of the plant, as well as approximately five sixths of the nitrogenous organic compounds, are chiefly composed of carbon, hydrogen, and oxygen, which the plant obtains from the carbon dioxide of the air and the water in the soil. The small amount of actual nitrogen in plant substance is derived from nitrogen salts in the soil, or partly from atmospheric nitrogen in case of legume crops. The ash of plant substance is derived from solutions of mineral matter in the soil. The greater part is of abundant elements, such as silicon, iron, chlorin, sodium, magnesia, and calcium; the smaller part is of less abundant elements, such as phosphorus and potassium.

The relative importance of these various forms of plant food has been determined by feeding them in various combinations to plants growing in water or sterilized sand. Such tests have shown that the relatively small amounts of nitrogen, phosphorus, and potassium in plant substance are the forms of plant food most essential to plant growth and most likely to limit soil productivity. See Table II.

Table II. The Amounts of Nitrogen, Phosphorus, and Potassium Removed from the Soil by Certain Typical Field Crops.

CROPS		Pounds Plant Food Removed per Acre		
Kind	Amount per Acre	Nitrogen	Phosphorus	Potassium
Corn (grain)	100 bu.	100	17	19
Corn (Stover)........	3 T.	48	6	52
Total..........	....	148	23	71
Oats (grain)..........	100 bu.	66	11	16
Oats (straw)..........	2½ T.	31	5	52
Total..........	....	97	16	68
Wheat (grain)........	50 bu.	71	12	13
Wheat (straw)........	2½ T.	25	4	45
Total..........	....	96	16	58
Timothy hay.........	3 T.	72	9	71
Clover hay...........	4 T.	*160	20	120
Cowpea hay..........	3 T.	*130	14	98
Alfalfa hay...........	8 T.	*400	36	192
Clover seed..........	4 bu.	* 7	2	3
Potatoes..............	300 bu.	63	13	90
Sugar beets..........	20 T.	100	18	157
Tobacco (leaf and stalks)..............	1000 lbs.	46	3.5	30
Cotton (lint)..........	1000 lbs.	3	0.57	3.5
Cotton (seed)........	2000 lbs.	63	10.63	19.3
Total (2 bales)..	3000 lbs.	66	11.20	22.8

NOTE: This table shows the approximate amounts of plant food removed from the soil by large yields of staple American field crops. The amounts of plant food removed will vary, of course, with the crop yields. Such variations may not be exactly proportional to yield, but for approximate calculations they may be considered so.

*The amount of nitrogen actually removed from the soil by legume crops varies greatly with the soil, the number of nitrogen gather-

ing bacteria in the soil, and the methods of disposing of the crop. On medium fertile, well inoculated soil, it is usually estimated that legumes draw about two thirds of their nitrogen from the air and one third from the soil. When legumes are cut for hay about one third of the total nitrogen content of the crop remains in the stubble and roots, while two thirds is removed in the hay. Thus, as a rule, when legume crop stubble and roots are plowed under there is neither loss or gain in soil nitrogen, but if the hay be fed to stock and the manure returned to the soil, or if the top part of the crop be plowed under as a green manure, there is an increase made to the soil's supply of nitrogen by reason of the amounts of atmospheric nitrogen which the crop has assimilated.

The food requirements of tobacco shown in this table are taken from Bulletin 139 of the Kentucky Agricultural Experiment Station; of cotton from Circular 583, Farmers' Co-operative Demonstration Work of the United States Department of Agriculture; and of all other crops from Bulletin 123 of the Illinois Agricultural Experiment Station.

The Indiscriminate Use of Commercial Fertilizers, Especially the Complete Fertilizer. The art of securing maximum profits from the use of commercial fertilizers is not based on the practice of supplying the soil with the estimated amounts of nitrogen, phosphorus and potassium removed by a given crop. Because a 100 bushel corn crop, for example, is known to remove from the soil about 148 pounds of nitrogen, 23 pounds of phosphorus, and 71 pounds of potassium, it does not follow that fertilizers should be applied to the land in such quantities as to annually provide these amounts of plant food. To do this would entail heavy expense, and use would not be made of the free nitrogen of the atmosphere and the reserve supplies of plant food in the soil that may be prepared for the use of crops by means of crop rotation, legume crop green manures, and thorough tillage. In other words, the expense for fertilizers would be made unnecessarily high by the amounts of plant food purchased in the fertilizer that could have been secured at less cost by the aid of legume crops and good farm practice.

In the majority of cases the purchase of complete fertilizers involves the purchase of some plant food that could

be provided, if necessary, at far less cost in other fertilizers, or that is not essential to the maximum productivity of the land. Rarely are soils so impoverished of plant food as to have their productivity limited by all three of the important elements of plant food, i. e., nitrogen, phosphorus, and potassium. In the great majority of cases phosphorus is the limiting factor in productivity, although there are cases where nitrogen or potassium or lime is the form of plant food so greatly lacking as to limit the soil's productivity. For these reasons the purchase of a complete fertilizer is quite likely to involve the purchase of unnecessary plant food and thus cause an expense of crop production from which there is no profitable return.

Let us illustrate this matter relative to the indiscriminate use of complete fertilizers by means of fertilizer cost figures taken from Table I for Chicago territory. Suppose that an attempt is made to purchase enough plant food in complete fertilizer to provide the amounts of plant food taken up by a 100 bushel corn crop (148 lbs. nitrogen, 23 lbs. phosphorus, and 71 lbs. potassium). The average complete fertilizer sold in the United States for $25.00 to $30.00 per ton, contains about 33 pounds of nitrogen, 70 pounds of phosphorus, and 33 pounds of potassium in one ton. Thus, at $30.00 per ton, it would require about 4½ tons of fertilizer costing $135.00 to supply sufficient nitrogen; about ⅓ ton costing $10.00, to supply sufficient phosphorus; and about 2⅙ tons costing $65.00, to supply sufficient potassium. A complete fertilizer specially mixed to correspond to this formula (the draft of a 100 bu. per acre corn crop) would cost at least $50.00 per ton and per acre. From these figures it may easily be seen that ordinary field crops cannot be profitably produced on the plant food contained in the complete fertilizer. An attempt to feed a crop all of its plant food from

a sack of complete fertilizer would most surely result in a loss to the producer. The cost of the plant food, so obtained, plus the costs for seed, plowing, planting, cultivating, and harvesting, would usually be so much in excess of the crop's value as to preclude any possibility of profit.

The figures in the preceding paragraph are given merely for the purpose of illustrating an extreme and theoretical example in regard to the use of commercial fertilizers and to show the utter impossibility of profitably feeding ordinary field crops all of their plant food out of a sack. In actual farm practice and in the growing of our staple field crops no attempt is ever made to actually supply the soil with the total amounts of plant food necessary to the production of a full crop. The common practice in districts using complete fertilizers is to apply 200 to 500 pounds per acre annually of the fertilizer. The fertilizer formulas are made to vary somewhat according to the crop grown—the percentage amount of potassium being comparatively higher in complete fertilizers used for tobacco and potatoes, and the percentage amount of nitrogen and phosphorus being comparatively higher in the so-called grass and grain fertilizers. Now, let us see the effect which an application of 500 lbs. of average complete fertilizer would have on the plant food requirements of a 100 bushel corn crop. The 500 pounds of average complete fertilizer, costing about $7.50, would contain 8.2 pounds of nitrogen, 17.5 pounds of phosphorus, and 8.3 pounds of potassium (in a fertilizer analyzing 2% ammonia, 8% phosphoric acid, and 2% potash). The entire inadequacy of such a fertilizer to supply the nitrogen and potassium requirements of a 100 bushel corn crop, or even a 40 or 50 bushel crop, may be easily seen. The amount of phosphorus, while nearly adequate, could be supplied in about one seventh of a ton of acid phosphate costing about

$2.50, or in about one twelfth of a ton of rock phosphate costing about 65 cents.

The cost of plant food in the complete fertilizer is always high when compared with the cost of more simple fertilizing materials carrying nitrogen, phosphorus, or potassium. If it is known that the soil is limited in its productivity on account of a phosphorus deficiency, phosphorus can be purchased cheaper in either rock phosphate, acid phosphate, or bone meal, than in the complete fertilizer. The same truth applies to either nitrogen or potassium deficiencies and their correction. In fact, the purchase of nitrogen and potassium in the complete fertilizer is commonly a pure waste of money, because the use of legume crops and good farm practice will provide these elements of plant food at little or no cost. Instances where nitrogen and potassium fertilizers can be used profitably are pointed out in succeeding paragraphs, but even in such instances the complete fertilizer is not a profitable carrier of these elements of plant food. In so far as cost is to be considered in the selection and use of fertilizers the complete fertilizer is an expensive carrier of the elements of plant food, and the farmer who fertilizes his land from a sack of manufactured complete fertilizer is forcing his business to carry an unnecessary burden of expense.

There is reliable evidence to show a net profit resulting from the use of complete fertilizers, but it can also be shown that, where net profits were secured by the use of complete fertilizers, better net profits were secured by correcting the plant food deficiencies of the soil with cheaper fertilizers carrying the needed plant food. Good business management demands that production costs shall be kept at the minimum. A high net profit is as much the result of low cost as of high gross income, and the farmer who attempts

to correct the plant food deficiencies of his soil with complete fertilizers is not destined to produce his crops at the minimum cost.

The comparatively high cost of plant food in the complete fertilizer is by no means the only drawback to its use. Wherever the use of complete fertilizers becomes a fixed feature of agriculture the effect on the ultimate productivity of the soil and on the systems of farming that grow up is deleterious to a marked degree. The application of complete fertilizers in such amounts as only partially meet the plant food requirements of crops tends to stimulate the absorption of plant food from the reserve supplies in the soil at a rapid rate during the early periods of such fertilizing methods. This results in ultimate unproductivity, unless the amounts of fertilizer are increased in proportion to the subtractions made from the reserve supplies of the soil, or unless the systems of farming and fertilizing are changed. The continuous application of complete fertilizers also reduces rapidly the humus supplies of the soil, forms a hard gritty metallic-like soil, and creates acid soils that need neutralizing with lime. In the older agricultural regions of the United States of America many soils are to be found that are almost entirely devoid of organic matter, in a poor physical condition, and with their available and reserve supplies of nitrogen and phosphorus reduced to a very low point from the long continued use of complete fertilizers. In this condition heavy applications of complete fertilizer are needed to get any kind of a crop.

Furthermore, the use of complete fertilizers tends to thwart the best farming and cropping systems. There is no reason for this, but it is a matter of fact nevertheless. Apparently the complete fertilizer becomes a staff of support to the farmer who gets into the habit of using it. He places

too much reliance on the power of the fertilizer to make a good crop, and too little reliance on crop rotation, farm manures, legume green manure crops, and thorough tillage. The complements of the complete fertilizer in American agriculture are usually continuous cropping and little if any use of farm manures, legume green manure crops or legume meadow and pasture crops. Eventually the farmer who places his reliance in complete fertilizers for the production of profitable crops will face increasing fertilizer bills and decreasing crop yields, because a system of farming based on the plant food of the complete fertilizer is inherently wrong. In the older agricultural regions there are thousands of farms that have been made comparatively unproductive from the long continued use of the complete fertilizer. By means of crop rotation, green manure legume crops, thorough tillage, and the addition of a bountiful supply of phosphorus the productivity of most of these soils could soon be increased very greatly.

It may be said that this picture of the deleterious effects on the soil from the use of complete fertilizers is overdrawn, and that the complete fertilizer will bring good results with no injury to the soil, if used in connection with crop rotation, green manures and animal manures. Undoubtedly many of the injurious effects on soil produced by continuous cropping and the complete fertilizer would be avoided, if the complete fertilizer were used in connection with crop rotation, green manure crops, and animal manures. But, even if there is need to correct some plant food deficiency in the soil by means of a commercial fertilizer, where is the advantage to be gained in purchasing nitrogen in the complete fertilizer at thirty to ninety cents per pound, when it can be had for temporary use in nitrate of soda for fifteen to twenty cents per pound, and free of cost in a permanently projected scheme

of agriculture by means of legume crops that can use the nitrogen gas in the atmosphere? Phosphorus costing thirty to forty cents per pound in the complete fertilizer can be purchased for about three cents per pound in ground phosphate rock. Potassium costing thirty to ninety cents per pound in the complete fertilizer can be purchased in muriate of potash for five to six cents per pound, in sulphate of potash for six to seven cents per pound, in kainit for seven to nine cents per pound, and can be liberated from the reserve supplies of most soils in the United States free of cost by means of crop rotation, green manure crops, farm manures and thorough tillage.

Conditions in General Agriculture Warranting the Use of the Complete Fertilizer. There are certain conditions, perhaps, in the practice of general agriculture where the complete fertilizer can be used to advantage. For example, a farmer purchases a farm having impoverished soil, and yet the farm is desirable on account of other considerations, such as roads, markets, and schools. He plans to establish a permanent system of farming that will build up this soil to a high state of productivity and keep it productive. This system of farming which he will employ includes the use of crop rotation, green manures and animal manures, to provide and maintain the supply of humus and nitrogen, and to liberate potassium from the reserve supplies of the soil. He plans to add phosphorus plant food to the soil in abundance for maximum crops by means of ground phosphate rock in which the actual phosphorus will cost but three cents per pound. Now, the establishing of a system of farming such as this cannot be accomplished in the twinkling of an eye. Raw phosphate rock is not immediately available to crops and its change to soluble and available forms of phosphorus is very slow, unless the soil is abundantly

supplied with decaying organic matter. The production of organic matter and nitrogen for this soil may be severely checked by a lack of available nitrogen, phosphorus, and potassium to give the "humus producing, nitrogen gathering" legume crops a good start.

Such a soil condition would give an opportunity for the use of a complete fertilizer for a year or two until the cheaper and more permanent scheme of soil building was under way. The complete fertilizer could be used advantageously to produce a heavy green manure crop to plow under and give an impetus to the permanent work of soil improvement. As soon as the soil had its available supplies of potassium released from the hitherto unavailable supplies in the soil, its nitrogen provided from the free nitrogen of the air, and its available phosphorus released from the cheap, raw phosphate rock added to the soil, there would be no further need for the expensive plant food of the complete fertilizer.

Of course, even under these conditions which may justify the use of the complete fertilizer as a temporary expedient, the same temporary feeding of crops can be accomplished at less cost through the purchase of available forms of plant food, as needed, in acid phosphate, muriate of potash, and nitrate of soda. An eight to ten ton dressing of farm manure per acre, mixed with about 250 to 300 pounds of acid phosphate, would start off a corn crop or a grain nurse crop with a legume catch crop, as well as, or better than, an expensive application of 300 to 500 pounds per acre of complete fertilizer. Also for quick results with grain, potato, or other crops, the needs of the crop can be temporarily met with applications of acid phosphate, muriate of potash, kainit, and nitrate of soda, in various amounts and combinations according to the crop and condition of soil at less cost than with the complete fertilizer.

Fertilizer Efficiency Dependent on Good Farming. The efficiency of commercial fertilizers is almost in direct proportion to the character of farming that accompanies their use. When commercial fertilizers are judiciously used as an adjunct to good tillage, crop rotation including legume crops, green manures, and animal manures, the maximum efficiency of the fertilizer will be realized in the production of crops. If too much reliance is placed on the fertilizer and too little attention given to the art of good farming, the efficiency of the fertilizer is greatly lessened. Good farming, so far as soil fertility is concerned, is essentially those practices that provide for a good physical condition in the soil, for the maintenance of an abundant supply of humus, for maintaining the soil's supply of nitrogen by means of legume crops that utilize atmospheric nitrogen, and for the use of some live stock to check the sale of plant food from the soil in large amounts.

These practices are the basis of permanent and profitable agriculture. Sometimes good farming needs supplementing with soil amendment to produce the best results, and when the commercial fertilizer is correctly used for this purpose it is efficient and profitable.

The indiscriminate use of commercial fertilizers, without proper consideration for good farming, or the soil deficiencies that good farming cannot correct, is more likely to result in loss than in profit. The commercial fertilizer has its place in the permanent, profitable system of agriculture for many soils; but its place is subordinate to that of good farming and its value dependent on the character of farming associated with its use.

CHAPTER VII

USE AND APPLICATION OF COMMERCIAL FERTILIZERS

Lime Fertilizers, Use and Application. Soils rich in lime compounds are well known to be very productive wheat and legume crop soils. Legume crops, such as clover and alfalfa, remove large amounts of lime from the soil and are often called "lime loving plants."

Lime takes a very important part in the fertility of the soil, not so much because it is a very essential form of plant food as because it functions as a neutralizing agent that combines with and neutralizes the acids that are continuously being formed in the soil from the decay of organic matter. All cultivated soils tend to become acid in nature, unless the natural supply of lime in the soil was very great. When a soil becomes somewhat deficient in lime and, therefore, acid in nature, productivity is greatly checked for many crops, especially clover, alfalfa, and other legumes, that do not thrive well in an acid soil. Nitrogen, phosphorus, and potassium may all be present in the soil in abundant amounts for good crops, and yet poor crops will result if lime is absent, and there is, therefore, an acid soil condition. An abundance of lime in the soil is desirable and essential to high fertility.

Lime also has a favorable effect on the physical condition of soils. In heavy clay soils an application of lime causes the cementing together of many groups of fine soil particles into compound particles of somewhat larger size, and thus the porosity and friableness of the soil are bettered. In a

sandy soil an application of lime improves capillarity and the water holding capacity of the soil as well as increases the productivity of the sandy soil for legume crops, which, in turn, improve the physical texture, especially when plowed under. In many of the older prairie regions of the United States where it is well known that clover does not thrive as well now as formerly, lime is often the fertilizing material that should receive the first consideration. When tests reveal soil acidity, the first step to be taken in building up the productivity of the soil and establishing a permanent, profitable system of agriculture, is to thoroughly lime the land and increase its productivity for clover or other legume. Clover and other legume crops will not grow well in acid soil, and thus, if an acid soil checks the production of legume crops, the benefits to be derived from humus producing and nitrogen gathering crops are lost, and lime is the limiting factor in the soil's productivity.

It is well known that land plaster (sometimes called sulphate of lime or gypsum), fresh burned lime and fresh slaked lime, are active stimulants in the soil that release potassium and phosphorus from the reserve supplies in the soil through hastening the decomposition of soil. On naturally rich soils well supplied with organic matter an application of these forms of lime will stimulate the soil to high productivity through the liberation of available plant food from the reserve supplies in the soil. For this reason the proverb has arisen "Lime makes the father rich but the son poor." The proverb is true enough, unless the system of farming provides for maintaining the humus and nitrogen supplies of the soil by means of animal manures and legume crops, and the supply of phosphorus by means of commercial fertilizers, in which case the son may become as rich as the father through the use of lime on his land.

In general, there is no necessity for the use of a lime fertilizer except to correct soil acidity. Soil acidity when very marked, is detected by inserting a small piece of blue litmus paper into a sample of soil. If the blue paper quickly turns red the soil is acid. Another simple method for detecting marked soil acidity is the ammonia test. This is performed as follows: fill a drinking glass about two thirds full of rain water (soft water), add a teaspoonful of the soil to be tested and a teaspoonful of strong ammonia. Stir thoroughly and allow to settle. If the liquid turns black or dark brown the soil is acid and in need of lime. Slight discoloration of the liquid would show such a small degree of acidity that the need of lime would be problematical. Unless acidity, as revealed by these tests, is very marked, it is well to proceed slowly with the purchase and use of lime. Experiment with a strip of limed land in a clover or alfalfa field and note the results. A test of this kind is far superior to the litmus paper and ammonia tests in revealing the needs of a soil for lime. Failure of clover, or poor clover crops, on old land, is also an index to soil acidity, although this test is not infallible.

In correcting soil acidity the choice of the kind of lime fertilizer to be used should depend on the cost and availability of the material. Ground limestone, marl, fresh burned lime, air slaked lime, and water slaked lime, can all be successfully used, though not similarly, for the purpose of correcting soil acidity.

Ground limestone and old air slaked lime are the safest and usually the cheapest materials to use. Either one of these materials will correct soil acidity, but will have little if any effect as a soil stimulant acting on the soil's reserve supplies of plant food. Either of these materials can be applied to the land at any season of the year most convenient

to the farmer, with no danger to crops. If spread in winter on sloping lands, some leaching may take place that could be avoided by spreading at some other season. The best time to spread a lime fertilizer, providing time permits, is in the spring of the year shortly before seeding time. The lime can be disked and harrowed into fall plowing or spread on stubble ground and plowed under, if spring plowing is to be practiced. Lime can be spread on land in the autumn just prior to fall plowing if desired, or, if time does not permit the doing of the work in either autumn or spring, it can be done during the winter months by scattering the lime on stubble ground to be spring plowed, or on fall plowing that is to be surface worked in the spring. Ground limestone or old air slaked lime can be applied to land in unlimited amounts with no danger to crops. Two tons per acre distributed every four to six years will usually be sufficient to sweeten an acid soil and keep it sweet and productive. Larger amounts at greater intervals of time can be applied, however, with no danger of injuring the productivity of the land.

Marl (a mixture of disintegrated limestone and clay and containing lime, phosphorus, and some potassium) is an excellent form of lime fertilizer. It is commonly found in many of the Northern regions of the United States, underlying peat beds. No better fertilizer can be had at any price for the light, sandy soils of large areas in the Northern timbered areas of the United States than a mixture of peat and marl that can be dug out of the drained lowlands. A thorough application of marl and peat, or marl and animal manures, to a light soil will greatly improve the physical condition of the soil, amend the natural phosphorus deficiencies, and promote the liberation of plant food from the reserve supplies in the soil, thus increasing productivity. Thousands of tons of this valuable fertilizer are scattered

throughout the glaciated areas of the Northern part of the United States, and at small expense the productivity of many farms could be greatly increased by its use.

Fresh burned lime, water slaked lime, and land plaster all contain a higher percentage of lime (calcium) than limestone, old air slaked lime, or marl, and, if used as fertilizers, should be applied in smaller amounts than limestone or marl. Eight hundred to twelve hundred pounds per acre every four or five years is usually a sufficient amount to correct all soil acidity and to supply crops with lime. All these forms of lime fertilizers are more or less caustic in nature and should not be applied to land after crops have been seeded, as the young vegetation may suffer injury. Whenever fresh burned lime, water slaked lime, or land plaster is to be used as a fertilizer, the material should be scattered on the land in the autumn, winter, or early spring, and plowed or harrowed into the land thoroughly before seeding.

In using lime fertilizers it is usually thought best not to apply lime to a soil in the same year that it is planned to distribute raw phosphate rock or bone meal, as the lime tends to retard temporarily the availability of the phosphorus. A better plan is to lime first and follow with the phosphate fertilizers in succeeding years.

Phosphate Fertilizers, Use and Application. It has been previously pointed out that natural phosphate rock is the cheapest of all carriers of phosphorus, but that the phosphorus which it contains is not immediately available to crops. Natural phosphate rock is the logical material to employ in correcting the phosphorus deficiencies of a soil and to give permanence to the soil's productivity at the minimum expense. In the improvement and renovation of worn out land that is in need of fertilizer amendments, however, there are many instances where it is profitable to

use an available form of phosphate fertilizer, such as acid phosphate, to supply crops liberally with phosphorus until it can be made available from natural phosphate rock.

Experience and experimentation have clearly shown that a liberal supply of organic matter in the soil is essential to the processes that make available to crops the phosphorus of natural rock phosphate, also that legumes have greater power to assimilate phosphorus from raw rock fertilizer than such crops as wheat, corn, cotton or potatoes.

It may be easily inferred from these facts that the best plan to follow in correcting the phosphorus deficiencies of a badly worn soil is, first, to use a sufficient application of available phosphorus (acid phosphate) to grow a legume green manure crop (sown, if desired, with a nurse crop of grain) that can be plowed under in connection with a heavy dressing of natural phosphate rock, and, then, to put a crop of clover on the land as soon thereafter as possible. After such preliminary steps have been taken and the soil is well supplied with organic matter and phosphorus in natural rock phosphate, there will be no further need for the use of expensive phosphate fertilizers such as acid phosphate. The real value of acid phosphate lies in its availability for the quick stimulation of some "nitrogen gathering, humus producing" crop that is essential to the cheap amendment of nitrogen deficiencies in the soil as well as for the liberation of phosphorus from natural rock phosphate.

On many soils where phosphorus is not yet very deficient, but where greater crops could doubtlessly be produced, if the soil were more liberally supplied with it, there is no need for profit in the use of acid phosphate. A liberal application of natural rock phosphate in connection with a green manure crop or with barnyard manure will accomplish the desired results at minimum cost.

In applying acid phosphate to land it is not advisable to apply it in large amounts and at infrequent intervals, because the excess of phosphates will become fixed in insoluble compounds unavailable to crops. It is best, therefore, to distribute an amount of fertilizer sufficient only for the needs of the current crop. From two hundred to three hundred pounds per acre would be ample for the needs of an average crop and would afford plenty of phosphorus to stimulate the growth of a heavy legume crop for the purposes mentioned in preceding paragraphs. The best time of the year to apply acid phosphate, dissolved bone, bone black, or other carriers of available phosphorus, is in the spring just prior to seeding. Harrowing or disking the fertilizer into the seed bed is preferable to plowing it under.

The methods of applying natural rock phosphate to land are somewhat different from the methods best adapted to acid phosphate. Rock phosphate can be applied at infrequent intervals in large amounts, if desired, and also at any season of the year that best suits the farmer and his other work. Rock phosphate undergoes decomposition slowly in the soil and there is a negligible loss from leaching even though the material is distributed in comparatively large amounts and at infrequent intervals. An application of 1,000 pounds per acre of rock phosphate every five or six years in a good crop rotation will provide a liberal supply of phosphorus for maximum crops. In case of a badly run down farm it would pay to apply a ton to the acre at the outset and to apply smaller amounts every three to six years (estimating the phosphorus needs of crops on the basis of 150 to 200 pounds of rock phosphate per acre annually). The work of spreading rock phosphate on the land can be divided up through several seasons and years, if desired, after the whole farm area has been covered and a rotation

has been started. Part of the fertilizer can be mixed with the barnyard manure and spread on the land during the winter, and another part spread on land just prior to either fall or spring plowing. After a farm has once been fertilized and a rotation started, the easiest and cheapest method for spreading phosphate fertilizer is to broadcast the fertilizer on pasture sod just prior to breaking, or, in case of a rotation without pasture, to apply the fertilizer just after an annual pasture, meadow, or green manure crop, and to plow it under with the accumulated manure and humus.

Potash Fertilizers, Use, and Application. In the growing of staple field crops there is rarely any real need for the use of potash fertilizers to supply the food requirements of the crops, providing methods of farming are followed that will release potassium from the large reserve supplies that exist in the majority of soils. Occasionally there are soils so deficient in potassium as to need real amendment in this respect. Drained swamp lands with peaty soils are often very deficient in potassium and must receive applications of potash fertilizers to make them truly productive.

Certain field crops such as potatoes, tobacco, and sugar beets draw heavily on potassium, which is essential to large yields and full development with these crops. In consideration of the fact that the gross income per acre for these crops is comparatively large and that a liberal supply of potassium in the soil will swell the gross income greatly at small proportionate expense, the judicious use of potash fertilizers is quite often advisable and productive of large profits. Field crops of this character are analagous to the truck gardener's crops which respond profitably to forcing with commercial fertilizers.

There are four forms of potash fertilizer that are practical in amending soils or feeding such special crops as

potatoes, sugar beets, and tobacco. These are: wood ashes not leached, kainit, muriate of potash, and sulphate of potash. All these fertilizers are water soluble and the potassium is readily available to crop roots. Wood ashes are rarely purchasable in any quantity. When produced on the farm or in local sawmills, it pays to save them and apply them to root crops or tobacco. The cost of potassium in kainit, muriate of potash, and sulphate of potash is nearly the same in most markets. Choice between these three forms of potash fertilizer should depend on the price (cost per pound of actual potassium,) although it is not advisable to use large amounts of muriate of potash on tobacco, potatoes, or sugar beets as a direct fertilizer. Muriate of potash can be successfully used to amend potassium deficiencies in peaty soils, but should not be applied directly to tobacco, potatoes, or sugar beets, whose quality it is likely to affect unfavorably.

Potash fertilizers are so easily soluble in water that considerable leaching may take place, if large amounts of fertilizer are used in excess of the amounts that can be absorbed by the current year's crop. For this reason the infrequent application of large amounts of potash fertilizers is not economical. It is better to apply potassium in an amount slightly in excess of the needs of the current year's crop, and to make applications frequently on soils deficient in this form of plant food. Furthermore, it is best to apply the potash fertilizer, wherever possible, to root crops or tobacco that will utilize the plant food so provided to the greatest profit. Unless soils contain an abundance of lime, the frequent use of potash fertilizers tends to produce an acid soil. If a soil is acid, it should be limed before potash fertilizers are used in order to make the potash fertilizer fully efficient, and to neutralize the acid portion of the fertilizer after the

potassium has been dissolved and utilized by crops. Potash fertilizers give the best results when applied jointly with lime, or when used on soils naturally rich in lime.

The best method for applying potash fertilizers is to broadcast the fertilizer early in the spring on fall plowing and harrow it thoroughly into the seed bed. In spring plowing the fertilizer should be broadcasted and harrowed in as soon after plowing and as long before planting as possible. It is not a good plan to drill in much potash fertilizer where it will come in direct contact with the plant roots, nor is it advisable to spread the fertilizer after the crop has started. These practices are likely to cause injury to crop roots and retard growth instead of stimulating it, particularly in dry seasons. The economical, safe method is to get the fertilizer thoroughly harrowed into the seed bed and in partial solution prior to planting.

The amounts per acre of potash fertilizers to secure best results vary greatly according to the fertilizer and the crop to be fertilized. Wood ashes, for example, contain from 2% to 10% of potash, (1.7% to 8.3% of the element potassium) and with the maximum percentage of potassium it would take 500 pounds of raw material to supply as much actual potassium as could be had in 100 pounds of sulphate of potash which contains 50% actual potash, (41.5% potassium). Kainit, also, usually contains about 12% potash (10% potassium) and would have to be applied in larger amounts than sulphate of potash to provide the same amount of potassium. From 300 to 500 pounds per acre of wood ashes or kainit is regarded as about the maximum amounts it is desirable to use. If it is desired to use a larger amount of potassium for a root crop than is contained in 300 to 500 pounds of wood ashes or kainit, it is better to use 200 to 250 pounds per acre of sulphate of potash. A top-dressing of

75 to 100 pounds per acre of sulphate of potash is ample for the needs of a tobacco crop, and 200 pounds per acre will provide a liberal supply of available potassium for a bumper potato crop.

Nitrogen Fertilizers, Use, and Application. The purchase of nitrogenous commercial fertilizers for general field crops is not good business. Live stock manures and legume green manure crops provide nitrogen at a cost so low as to prohibit any real competition from other nitrogen carrying materials. The only conditions of general farming that warrant the use of commercial nitrogen fertilizers are in the early work of building up a farm of impoverished soil. Nitrogen deficiency in an impoverished soil needs attention prior even to phosphorus, potassium or lime. The legume crops that are capable of utilizing atmospheric nitrogen cannot start and thrive on a soil deficient in available nitrogen. The first step in the cycle of a plan to establish a permanent system of agriculture on an impoverished soil is to replenish the nitrogen supply.

In such a case resort must be had to the commercial nitrogen fertilizer, unless animal manures are available. The best commercial nitrogen fertilizers are nitrate of soda, sulphate of ammonia, dried blood, and tankage. In most cases nitrogen can be purchased as cheaply in nitrate of soda as in any other form (see page 281). If dried blood, sulphate of ammonia, or tankage, can be purchased at a price that will provide nitrogen more cheaply, they may be given the preference. It should be remembered, though, that the nitrogen in tankage is not readily available, and, therefore, this fertilizer is not as quick acting as the others.

An application of 300 to 400 pounds per acre of nitrate of soda is none too much to use in case of a soil badly impoverished of nitrogen, when it is desired to quickly stimu-

late the growth of "nitrogen gathering, humus producing" crops to form the basis for a permanent supply of cheap nitrogen. Three hundred pounds of 16% nitrate of soda would contain 48 pounds of available nitrogen and this would be none too much for a thrifty legume crop of any kind, or a grain crop that was being used as a nurse crop. But this amount of nitrogen fertilizer would create a very heavy acre expense (about $9.00 per acre) and would hardly be justified under the conditions mentioned. It would be a wiser plan usually to apply 100 to 150 pounds of nitrogen fertilizer per acre, together with lime, if needed, thus getting the legume crops started as cheaply as possible, and depend on animal manures and green manure legume crops as soon as possible to build up the supply of nitrogen plant food in the soil.

Nitrogen fertilizers can be applied to land and to crops by various methods. They will cause a rank growth of vegetation and for that reason are often used as a top-dressing on meadows. They may cause rank and weak grain straw on some soils, when care should be exercised in giving nitrogen stimulation to the grain crop. In general, if there is a real need for the use of a nitrogen fertilizer in general farming, the fertilizer can be used to best advantage in giving a quick start to an annual legume crop or to a seeding of meadow grasses and clovers. In such an event a portion of the fertilizer can be broadcasted and harrowed into the seed bed prior to seeding and another portion used later on as a top-dressing, or, if desired, the entire amount worked into the land prior to seeding.

The actual cases where a nitrogen fertilizer can be profitably used are very rare. Money spent on commercial nitrogen fertilizers is usually wasted, and they should be shunned by a majority of farmers growing staple field crops.

Fertilizer Machinery. Commercial fertilizers can be spread on land fairly well by hand methods either from the wagon or from piles on the land. But these methods involve much hard work and fail to give the even distribution that is essential to the best results. The work of distributing commercial fertilizers should be done by machinery wherever possible. Machine distribution gives the maximum efficiency to a given amount of fertilizer on account of the evenness of distribution, greatly reduces the amount of hard work involved and also permits of rapid work—an item of importance when lime or phosphate rock must be unloaded and distributed from a railway car.

There are numerous machines and attachments for standard farm machines made for the special purpose of distributing commercial fertilizers. In general, these machines are planned to distribute fertilizers by either of two

Photo by courtesy American Seeding Machine Company.

A machine that broadcasts ground limestone, ground phosphate rock, or other fertilizer, on land. The practical way to apply commercial fertilizers.

methods, (1) broadcasting the fertilizer on the surface of the land, and (2) drilling the fertilizer into the seed bed along with the cotton, corn, potato, or other seed. The broadcasting method is usually the preferable one, especially when lime, potassium, and phosphate fertilizers are being used to amend soil deficiencies. Large broadcasting machines can be had that will distribute fertilizers evenly and rapidly. They are provided with large hoppers, screens to take out lumps and sticks, large, wide tired wheels, and force feeds to give an even distribution of the fertilizer. The amount of fertilizer per acre can be regulated in much the same manner as the amount of seed per acre is regulated on a grain drill.

When fertilizers are evenly distributed with a good broadcasting machine, and thoroughly harrowed into the seed bed, the maximum efficiency of the fertilizer will usually be realized at the minimum cost for distribution.

PROBLEMS AND PRACTICUMS

(1) What are the approximate plant food requirements of a wheat crop yielding 22 bu. per acre? What would it cost to supply all the plant food (nitrogen, phosphorus and potassium) for this crop, if the plant food were supplied from a complete fertilizer analyzing 4% ammonia, 8% phosphoric acid, and 4% potash, and costing $30.00 per ton? What would it cost to supply these same amounts of plant food from acid phosphate analyzing 16% phosphoric acid and costing $18.00 per ton; muriate of potash analyzing 50% potash and costing $45.00 per ton; and nitrate of soda analyzing 15% nitrogen and costing $60.00 per ton? See pages 296, 282.

(2) Perform the simple litmus paper and ammonia tests for soil acidity described in this chapter, using a soil sample of your home farm or some local farm.

(3) Why is the purchase of nitrogen fertilizers for field crops usually a waste of money?

(4) Outline a plan for the economical distribution of lime, phosphate rock, or potassium fertilizers on a farm. Consider the season of the year, the time allowed by railways for unloading a car, the distance of the farm from the railway siding, the amount of fertilizer to be used per acre, the equipment for unloading and distributing, and the number of men and horses necessary and desirable to accomplish good work. Estimate the cost per acre for unloading and distributing.

(5) Select two or three of the rotation plans and diagrams that were called for in the questions accompanying Chapters VI to XI, Part II, preferably those that apply to your local conditions, and insert a rational plan for soil amendment with fertilizers. If the local conditions are such that fertilizer amendments are unnecessary, use theoretical diagrams presupposing a need for lime, phosphorus or potassium amendment. This plan should show first of all the desired soil amendments or the results it is desired to accomplish with special crops in the rotation, such as potatoes, sugar beets, or tobacco. It should further show the kinds and amounts of fertilizers to be used; the place in the rotation for applying the fertilizer or fertilizers, and the time of year the fertilizers are to be applied. Supplement the diagram with a thorough explanation and discussion. Give your reasons for the plan of amendment you have outlined.

CHAPTER VIII

EXPERIMENT STATION REPORTS

In the following paragraphs quotations are given from the bulletins of several Agricultural Experiment Stations concerning the use of commercial fertilizers in general farming. Space does not permit the use of excerpts from commercial fertilizer bulletins in every agricultural region of the United States. Selections have been made, therefore, from a few bulletins that it is believed will best show the principles and practice for the general farming conditions of the United States.

In order to avoid confusion in regard to terms pertaining to phosphorus, all references in these bulletins to phosphoric acid have been changed to the common and comparable basis of the element phosphorus. All references to potash and potassium are taken exactly from the bulletins. These terms are often used indiscriminately in agricultural publications, but the reader will not be confused, if he remembers that potash is a chemical compound containing 83% potassium.

The Cut-over Lands of South Mississippi. Bulletin 160 Mississippi Agricultural Experiment Station (pp. 12-13). The results of hundreds of tests with fertilizers conducted here under all classes of crops bear out the evident conclusion drawn from a study of our soil analyses that phosphorus is the mineral element most seriously lacking in these soils. * * * Potash is still relatively high as compared to phosphorus, there being about twenty times as much potash in soil and subsoil as there is phosphorus. This fact is also borne out by practical or actual results, for the addition of potash either alone or in combination with phosphorus and

nitrogen has given little increase of crop. * * * Nitrogen is necessary even on freshly cleared lands here and must from the start be supplied either with commercial fertilizers or by growing legume crops. Nitrogen when purchased in fertilizers costs so much, is so easily lost from the soil by leaching or oxidation, and is so cheaply supplied by leguminous crops so easily grown here either alone or as catch crops, that it is really extravagant to buy this nitrogen in any well planned system of cropping. * * *

The fact is, people have gone fertilizer mad, as it were, and have learned to depend almost entirely on buying plant food in a sack rather than on manufacturing the same on the farm by growing leguminous crops and by keeping more live stock from which to make manure. From the experience with the matter at this station, it would seem that the fertilizer question resolves itself into the simple proposition of adding more humus to the soil by growing more leguminous crops which at the same time will supply the necessary nitrogen, leaving only the phosphorus to be purchased, which in the presence of an abundance of rotting organic matter can be supplied as raw phosphate rock.

Thus, instead of spending $20.00 a ton for a complete fertilizer, which, generally speaking, would contain about $2.00 worth of potash and $9.00 worth each of nitrogen and phosphorus, the farmer could on these soils dispense with the potash entirely, and could supply the nitrogen with leguminous crops and animal manures, and instead of paying 12½ cents per pound for phosphorus in acid phosphate, could, by increasing the humus content of his soils, get practically the same results by using raw phosphate rock at a cost of three cents per pound for phosphorus. We would by no means recommend that this substitution of raw phosphate rock for acid phosphate be done indiscriminately; for, unless the organic matter is present in quantity, the result would be very disappointing. There is so much doubt as to the financial benefit from the addition of potash to fertilizers used here that we do not hesitate to advise its elimination, except in individual instances where the farmer has satisfied himself that it does good.

Wheat Growing in Kentucky. Bulletin 155 Kentucky Agricultural Experiment Station (pp. 50-51). * * * There is only one safe rule, so far as fertility is concerned, for producing good crops of any kind, and that is to keep up the fertility of the soil by a judicious rotation of crops, the use of all the manure that can be produced on the farm, and the purchase of whatever mineral plant food the soil may be deficient in. * * *

* * * The solution of the problem of fertility, then, is, as stated, to keep up a good humus supply by a good rotation containing clover and other legumes and by the use of manure, supplemented by the purchase in sufficient quantity of the element which may be deficient, which is usually phosphorus. It is no doubt profitable on many soils to use a high grade, complete fertilizer, to give the crop a good start; but it should always be borne in mind that the use of it alone will not keep up the fertility of the soil.

Any soil, no matter how abundantly supplied with the mineral elements of plant food, may become so deficient in organic matter that the availability of the mineral plant food will not be sufficient to meet the needs of the crop. In such cases the use of commercial fertilizers may give profitable results, and may be used until a supply of organic matter is restored to the soil.

Soil Fertility Problems in Kentucky. Extension Circular, May, 1913, Kentucky Agricultural Experiment Station (pp. 7-9). The large quantities of organic matter necessary to keep a soil in good condition cannot be produced on soils deficient in phosphorus. The first essential, then, in the improvement of such soils, after correcting acidity, is the addition of an adequate supply of phosphorus. The question at once arises as to what form it is best to use. We realize that in discussing this question we are treading upon disputed ground.

Let us first consider the cost. A ton of 6% acid phosphate costs $16.00 and affords 120 pounds of phosphorus. A ton of 12% raw ground phosphate rock costs $6.00 to $7.50 in most parts of this State, and affords 240 pounds of phosphorus. But more than two tons of raw ground phos-

phate rock may be brought for $16.00, affording not less than 500 pounds of phosphorus against 120 pounds in the acid phosphate. When applications amounting to five or six tons have been made on an acre of the ordinary thin soils of the State, at a cost of $30.00 to $40.00, it will contain as much phosphorus as the high priced lands of the Blue Grass Region selling for $125.00 to $150.00 per acre, and in many cases can be made quite as productive. This content would be sufficient, under good conditions, to furnish available phosphorus for 100 bushel corn crops. This of course requires capital, but no business can be conducted without capital. * * *

* * * On soils deficient in organic matter, acid phosphate may be expected to give better results than raw ground phosphate rock. Also acid phosphate may be expected to give better results the first year than raw ground rock. But in a continued process of soil building, rock phosphate used in connection with sufficient decaying organic matter may be expected to give the most profitable results. * * *

* * * The following table gives the results of experiments begun at Burnside, Kentucky, in 1908, on a very badly worn piece of land. The analysis of this soil shows in the surface 7 inches: 14,600 pounds of potash, 1,860 pounds of nitrogen, and 666 pounds of phosphorus.

Table III. Fertilizer Experiments on Badly Worn Land in Kentucky

Plot	SOIL TREATMENT Amounts of Fertilizer per Acre	Bu. Corn 1909	Bu. Oats 1910	Pounds Clover Hay 1911	Bu. Corn 1912
1.	Rock phosphate 2,000 lbs. Muriate of potash 400 lbs.	3.8	9.3	2,436	32.9
2.	No treatment	7.0	9.0	668	9.5
3.	Acid phosphate 800 lbs. Muriate of potash 400 lbs.	11.3	11.9	2,168	45.7
4.	Acid phosphate 800 lbs.	17.7	13.6	2,328	43.5
5.	No treatment	20.4	14.0	1,292	30.3
6.	Muriate of potash 400 lbs.	11.9	10.5	764	17.6

Note: In these experiments an application of fertilizers was made when cowpeas were planted in 1908. Rock phosphate was used at the rate of one ton per acre; acid phosphate 800 pounds per acre (equal in money value to the rock phosphate), and muriate of potash 400 pounds per acre. Manure was added each year equivalent to the crop removed. A second application of like amounts was made in the spring of 1912. Both times the fertilizers were applied broadcast and plowed under. The plan is to make only one application of fertilizers in a rotation. No nitrogen is used in this experiment for the reason that it is not profitable to restore nitrogen to a soil by purchasing it in commercial form.

* * * It will be observed that the effects of raw ground phosphate rock did not show up very much until the clover crop was reached. The reason for this is that the soil was very deficient in organic matter and nitrogen, and that the plot on which the rock phosphate was used was decidedly the poorest in nitrogen. * * * In the summer preceding the corn crop (1909), all the plots were sown to cowpeas which were turned under and followed by a rye cover crop which was also turned under. Where acid phosphaté was used there was practically twice the growth of cowpeas and rye as on the plots where acid phosphate was not used. It is thus readily seen that the acid phosphate plots had the advantage in the beginning over the rock phosphate plot. The idea was to give rock phosphate a severe test in the process of restoring fertility. It is interesting to note that potash has shown no appreciable results on any of the crops.

From our experience in this experiment, we are led to recommend that in beginning the restoration of a badly worn soil deficient in phosphorus, it is best to use an application of acid phosphate in growing a cowpea crop turned under with a liberal application of raw ground phosphate rock, to be followed with clover as soon as possible. Clover seems specially able to utilize the rock phosphate. The clover turned under, pastured, or fed with the manure returned, furnishes available phosphorus as well as nitrogen for succeeding crops. On soils fairly well supplied with organic matter rock phosphate may be used to begin with.

Shall We Use Natural Rock Phosphate or Manufactured Acid Phosphate for the Permanent Improvement of Illinois Soils? Circular 127, Illinois Agricultural Experiment Station (pp 16-18). This bulletin, prepared by the Illinois Agricultural Experiment Station, gives a thorough resume of all experimental work at the Ohio, Maryland, Pennsylvania, Maine, Massachusetts, Rhode Island, and Illinois stations, on the comparative merits of raw rock phosphate and acid phosphate for general field agriculture. While the conclusions reached in each case are quite similar, the experiments at the Ohio station are the most comprehensive, because a definite plan of plowing under organic matter accompanied the application of the fertilizers, as would be done in good farm practice. Excerpts are, therefore, given from the investigational work of the Ohio station only.

* * * The investigations of the Ohio Agricultural Experiment Station cover twelve years of undoubtedly as careful field experimentation as has ever been conducted. In these investigations three different and entirely distinct fields are used, and in each field a double comparison has been made between raw rock phosphate and acid phosphate. A three-year rotation is practiced, consisting of corn the first year, wheat with clover seeding the second year, and the regular clover crop the third year, these crops being rotated so that every crop is represented every year.

In each field there are two plots that are treated with manure alone, which is applied to the clover sod at the rate of eight tons per acre and plowed under for corn, no further application being made for the wheat or clover. There are two other plots in each field treated with the same kind and amount of manure to which has been added 40 pounds of raw phosphate rock with each ton of manure, and there are still two other plots on which, likewise, the same quantity and kind of manure is used, to each ton of which has been added 40 pounds of acid phosphate.

The following tabular statement gives the average of all of the yields obtained during the twelve years for each field.

Table IV. Ohio Experiments with Manure, Raw Rock Phosphate, and Acid Phosphate. Average of 12 Years. Duplicate Tests on Each Field.

Soil Treatment	Field A	Field B	Field C	Average
CORN—BUSHELS PER ACRE				
Manure alone	47.2	63.6	53.3	54.7
Manure and Rock Phosphate	56.4	69.5	58.2	61.4
Manure and Acid Phosphate	54.6	70.8	62.0	63.1
WHEAT—BUSHELS PER ACRE				
Manure alone	20.4	21.7	17.2	19.8
Manure and Rock Phosphate	23.4	30.4	24.6	26.1
Manure and Acid Phosphate	23.8	29.4	25.7	26.1
CLOVER HAY—TONS PER ACRE				
Manure alone	1.99	1.34	.83	1.39
Manure and Rock Phosphate	2.47	1.90	1.79	2.05
Manure and Acid Phosphate	2.23	1.76	1.92	1.97

It will be seen that, as an average of all the data from the 12 years' experiments, the increase from the raw rock phosphate has been practically identical with that from the acid phosphate, while the cost of treatment was twice as great with the acid phosphate as with the raw rock. Furthermore, twice as much phosphorus has been applied in the application of raw rock as in the application of acid phosphate, so that at the close of the twelve years the raw phosphate plots still contain as much applied phosphorus as the total application made in the acid phosphate. It will be observed in case of the clover crop, which has power to secure nitrogen from the air, or should have, if the soil contains

plenty of lime, the rock phosphate has produced distinctly better results than the acid phosphate, the average difference amounting to .08 of a ton per acre, or 64 cents' worth of hay at $8.00 per ton.

Fine ground natural rock phosphate, carrying 12% to 12½% of the element phosphorus, can be delivered in car lots to Central Illinois for a cost of $6.50 to $7.50 per ton of 2,000 pounds. Acid phosphate (with 7% phosphorus) commonly costs from $15.00 to $18.00 per ton in Central Illinois.

Shall We Use "Complete Commercial Fertilizers" in the Corn Belt? Circular 165, Illinois Agricultural Experiment Station (pp. 3, 4, 5, 7, 8, 9, 13, 14, 15, and 16). This bulletin is an excellent summary of the facts about "complete fertilizers" for the agriculture of the Middle West. Numerous excerpts are here made from it that will present considerable experimental evidence about "complete fertilizers" in condensed form and popular language.

* * * The most common "complete fertilizer" in the United States has a composition known as 2-8-2, which means it contains in 100 pounds the equivalent of 2 pounds of ammonia, 8 pounds of available phosphoric acid, and 2 pounds of potash, or, in terms of actual plant food elements, one ton of such fertilizer contains about 33 pounds of nitrogen, 80 pounds of phosphorus, and 33 pounds of potassium; and, as a general average, such a fertilizer is sold at retail for $20.00 to $30.00 per ton.

A 50 bushel crop of corn takes from the soil 75 pounds of nitrogen, 12 pounds of phosphorus, and 36 pounds of potassium; and, in proportion to the yield, other grain crops have approximately the same requirements. Such a crop would require more than a ton per acre of such fertilizer to supply the potassium, or more than two tons to furnish the nitrogen, or from $4.00 to $6.00 worth of "complete fertilizer" to provide even the phosphorus for one acre of corn yielding 50 bushels. * * *

* * * The ordinary "complete fertilizer" is made by taking one ton of ground phosphate rock and adding to it about one ton of sulphuric acid and two tons of "filler," together with a small amount of nitrogen and potassium; thus producing four tons of "complete fertilizer" of the average composition noted above, with no more phosphorus in the four tons than was contained in the one ton of raw rock phosphate.

Fine ground natural rock phosphate can be delivered at the farmers' railroad stations in most parts of the corn belt for less than $8.00 per ton, while the four tons of "complete fertilizer" containing the same amount of phosphorus would cost the same farmers more than $80.00 as an average. About a year ago I found one farmer in Illinois who had purchased four tons of such a "complete fertilizer" at a cost of $114.00 ($28.50 per ton), whereas for $7.00 he could have purchased in raw rock phosphate, delivered at his station, the same amount of phosphorus as was contained in the four tons of "complete fertilizer." Long continued investigations clearly establish the fact that by growing and plowing under leguminous crops, either directly or in manure, he could have secured plenty of nitrogen from the air, and have liberated not only abundant potassium from the inexhaustible supply contained in the soil, but also phosphorus, as needed, from fine ground natural rock phosphate plowed under in connection with the decaying organic manures.

I have given the above figures in order to show something of the enormous profit from the manufacture and sale of commercial fertilizers, as well as to show that it is not necessary for the farmer to buy small amounts of three different elements of plant food, but rather that he should buy large amounts of one element—so far as we can judge from the broad facts concerning the supply of the plant food elements in normal soils and in the air, the requirements of the staple farm crops for these elements, and the composition and cost of the "complete fertilizer" as well as of ground natural rock phosphate. * * *

* * * The Indiana Agricultural Experiment Station published in April, 1912, Bulletin No. 155, entitled "Results

of Co-operative Fertilizer Tests on Clay and Loam Soils." * * * The authors have used reasonable prices for farm products and have also been fair to the fertilizer industry in regard to the cost of fertilizers.

They report fifteen different tests in eleven different counties with the use of the ordinary 2-8-2 fertilizer for corn, and they show that, as a general average, for every dollar invested in such fertilizers the value of the increase in the corn crop amounted to $1.59.

They also report eighteen different tests in sixteen different counties with the use of 4-8-4 fertilizer on corn, and show that for every dollar invested in "complete fertilizer" of this composition the value of the increase in the corn crop was worth only 83 cents.

Furthermore, they report nineteen different tests in thirteen different counties with the use of 4-8-4 fertilizer on wheat, and for every dollar invested in the fertilizer the value of the increase produced amounted to $1.30.

They report six different tests in four different counties with the use of "complete fertilizers" of different composition on oats, and, as an average, every dollar invested in the fertilizer produced an increase in the oat crop valued at 31 cents.

Finally, they report thirteen different tests in seven different counties with the use of 4-8-4 fertilizers on potatoes, and for every dollar invested in the fertilizer the increase produced in the potato crop was worth $1.04.

It will be seen that, as a general average of the fertilizer tests on corn, wheat and oats, the investment of $1.00 in "complete commercial fertilizers" paid back only 94 cents.

In the summary of this bulletin occurs the following significant statement: "Phosphorus and potash gave a greater profit per dollar invested in the fertilizer, than complete fertilizer, on both corn and wheat. In nearly all experiments with all crops on clay and loam soils phosphorus was found to be the most effective of the fertilizer elements."

Thus the data reported show that while 4-8-4 fertilizer for corn paid back only 83 cents out of each dollar invested, when the nitrogen was omitted from the fertilizer it then

paid back $1.19 for each dollar invested. In other words, by omitting the nitrogen the net loss of 17 cents was changed to a net profit of 19 cents.

Furthermore, as may be seen from the results mentioned above, when both the nitrogen and potassium were reduced by one half (from 4-8-4 to 2-8-2) the net return per dollar invested was changed from a loss of 17 cents to a profit of 59 cents; and, in harmony with the above quotation, the authors of this bulletin show that when the nitrogen was entirely omitted from the 2-8-2 fertilizer used for corn, the net profit per dollar invested rose from 59 cents to $1.24.

This series of experiments did not include any tests with the use of phosphorus alone, but Circular Number 10 of the Indiana Agricultural Experiment Station gives the results from a comparative test with acid phosphate and raw rock phosphate conducted in Scott County over a period of four years with a two year rotation of corn and wheat.

If we allow $15.00 per ton for the acid phosphate and $7.50 per ton for the ground natural phosphate, and figure the crops at the same prices as were used by the Indiana Station (35 cents a bushel for corn and 80 cents a bushel for wheat) we find that for each dollar invested the acid phosphate paid back $2.45, and the raw phosphate $3.41 as net profit.

In commenting upon these experiments in Indiana Circular Number 10, Director Goss emphasizes the fact that the acid phosphate gave better results for the first two years, but that during the third and fourth seasons, the rock phosphate produced very striking results, even forging ahead of the acid phosphate. * * *

* * * In a five year rotation of corn, oats, wheat, clover, and timothy, grown on five different series of plots, so that every crop may be represented every year, the Ohio Agricultural Experiment Station has tested the use of "complete commercial fertilizers" for a period of eighteen years. As a general average the "complete fertilizers" have cost the Ohio Station $19.78 per acre for the rotation, and the increase in crops (at average Ohio prices of 40 cents a bushel for corn, 30 cents for oats, 80 cents for wheat, $8.00 a ton for hay,

$2.00 a ton for straw, and $3.00 a ton for corn stalks) has been worth $32.84, thus showing a profit of $13.06 for the rotation, or 66 cents for each dollar invested.

* * * In comparison with "complete fertilizers," phosphorus was used alone in these Ohio experiments; and the same Ohio Circular (Number 120) shows that $2.60 invested in phosphorus gave a net profit of $13.93 per acre per rotation. In other words, as an average of these most trustworthy investigations covering eighteen years, the actual profit per acre from $2.60 invested in phosphorus was 87 cents greater than that from $19.78 invested in the "complete fertilizers." The fact is that the expenditure for nitrogen and potassium was worse than useless; for, when the net returns are computed as above, it is seen that the actual profits were reduced 87 cents per acre by the purchase of nitrogen and potassium. It will be noted that for every dollar invested in phosphorus alone there was a net profit of $5.36, compared with the average of 66 cents from the "complete fertilizers." Of course the profit from phosphorus would have been still greater, if the increased crops produced by the phosphorus had been returned to the soil to a considerable extent, either in farm manure or in green manures and crop residues, as they would be in rational systems of farming.

If one invests $2.60 in phosphorus and receives $16.53 therefrom in increased crops, then it would seem that the man who has any more money to invest in fertilizers would buy more phosphorus, rather than spend it for nitrogen and potassium which fail to pay even their cost. It may be added that where nitrogen was used alone in these same Ohio experiments, it paid back only 58% of its cost, while nitrogen and potassium together paid back only 52% of their cost. Potassium alone did not pay its cost, but when used in addition to phosphorus each dollar invested in potassium paid an apparent profit of 22 cents in five years, which is less than 5% per annum.

Another very important point to consider is that the Ohio Experiment Station did not buy the "complete fertilizers" used in these experiments, but bought the ingredients

and mixed them at about two thirds of the average cost of the ready mixed "complete fertilizers." If we figure the cost of the "complete fertilizers" on the basis of average retail prices for the ready mixed "complete fertilizers," the average profit of 66% derived from the use of "complete fertilizers" in the five-year rotation at the Ohio Station, shrinks to about 11% or to about 2% per year on the money invested.

* * * These very valuable Ohio experiments furnish additional definite proof of the need of purchasing phosphorus in profitable systems of permanent soil improvement; but the results do not justify advising the use of "complete fertilizers" in general farming on normal corn belt soils; and, for the sake of maintaining general industrial prosperity, as well as for their own sake, farmers and landowners should be encouraged to invest their money in the positive and permanent improvement of their soils, rather than to spend it for small amounts of high priced "complete fertilizers" in systems of ultimate land ruin, which will finally leave them too poor ever to adopt systems of permanent agriculture.

* * * The long continued investigations conducted by such public service institutions as the agricultural experiment stations, clearly show to the careful reader that, in profitable systems of general farming, nitrogen should be secured from the air, potassium should be liberated from the inexhaustible supply naturally contained in all normal corn belt soils, and that phosphorus should be purchased and applied liberally in low priced, fine-ground natural rock phosphate, ground limestone (likewise a low priced natural fertilizer) also being used where needed.

The Fertility in Illinois Soils. Bulletin 123, Illinois Agricultural Experiment Station (p. 209). * * * On land deficient in phosphorus the standard rule should be to apply phosphorus equivalent to 25 pounds of the element per acre per year, remembering that a 100 bushel crop of corn removes 23 pounds of phosphorus. To supply 25 pounds of phosphorus will require 200 pounds of good steamed bone meal costing about $2.50, or 200 pounds of good raw rock

phosphate costing about 80 cents, or 12½ tons of average fresh farm manure, or the manure that can be made from 200 bushels of corn costing $80.00 to $100 as feed.

* * * Probably the most practical and profitable method of maintaining the supply of phosphorus is by applying 1,000 pounds per acre of raw phosphate rock once every five or six years, preferably in connection with all available farm manure, and for the first two or three applications one ton per acre of the phosphate may well be used. It will remain in the soil until removed by crops unless subject to surface washing.

If one adopts the rule that when one applies phosphorus it must be at the rate of at least 25 pounds per acre for each crop in the rotation (not 25 pounds of so called phosphoric acid, nor 25 pounds of so called bone phosphate, but 25 pounds of phosphorus) he will then be proof against the misleading and ruinous practice of using ordinary so called "complete commercial fertilizers," for he will at once discover that to buy 25 pounds of phosphorus in such fertilizers will cost from $8.00 to $10.00, and that the amounts he can afford to apply of such fertilizers will not furnish more than ¼ to ½ as much phosphorus as is actually removed from the soil in good crops.

Fertilizer Experiments with Sugar Beets. Bulletin 115, Colorado Agricultural Experiment Station. (pp. 13, 14 and 23). The fertilizer experiments noted in this bulletin are particularly interesting in that they show so plainly the great difference in the general fertilizer requirements of the Western soil areas of the United States as compared with the soil areas of the Middle Western, Eastern and Southern states. These experiments, conducted on the comparatively new soil of the Western states where the per cent of natural phosphorus in the soil is comparatively high and the percent of natural nitrogen comparatively low, show plainly that at the present stage of general agriculture in the Western states, nitrogen is the element of plant food demanding most consideration by the farmer. The need for soil amendment as regards phosphorus is not an important feature of

Western agriculture at the present time as is the case in parts of the Middle Western, Eastern and Southern regions of the United States.

Table V. Fertilizer Experiments with Sugar Beets, Andrews Farm, Lake Park, 1905, Colorado Agricultural Experiment Station.

Plot No.	Kind of Fertilizers.	Lbs. per acre	Cost of fertilizer per acre	Yield clean beets tons per acre	Gross income beets per acre	Net income after taking out fertilizer cost
			Dollars		*Dollars*	*Dollars*
1.	Acid bone meal	193	1.93	15.61	78.05	76.12
2.	Acid bone meal	192				
	Sulphate of potash	96	5.58	16.81	84.05	78.47
3.	Sulphate of potash	142	4.47	15.14	75.70	71.23
4.	Sulphate of potash	100				
	Nitrate of soda	199	9.12	17.89	89.45	80.33
5.	Nitrate of soda	426	12.78	18.60	93.00	80.22
6.	No fertilizer	......	......	14.76	73.80	73.80
7.	Nitrate of soda	212	6.36	16.16	80.80	74.44
8.	Nitrate of soda	214				
	Acid bone meal	215	9.28	15.93	79.65	70.37
	(Complete fertilizer)					
9.	Acid bone meal	187				
	Nitrate of soda	187				
	Sulphate of potash	94	11.06	14.71	73.55	62.49
10.	No fertilizer	.....	......	12.18	60.90	60.90
11.	No fertilizer	......	......	13.63	68.15	68.15

Table VI. Fertilizer Experiments with Sugar Beets. The Residual Effects of Manure and Fertilizers. Colorado Agricultural Experiment Station.

Plot No.	Kind of Fertilizer Applied in 1903 only	Am'ts fertilizer per acre	Tons Yield per Acre			
			1903	1904	1905	Average 3 Years
		Tons				
1.	Cow manure..............	60	24.11	19.68	15.82	19.87
2.	Cow manure..............	30	25.10	20.31	14.57	19.99
3.	Cow manure..............	15				
		Lbs.				
	Nitrate of soda............	150	25.25	19.13	16.94	20.44
4.	Nitrate of soda............	150	25.67	19.28	17.78	20.91
5.	Nitrate of soda............	150				
	Raw bone meal............	200	25.61	17.98	16.10	19.89
6.	No fertilizer...............	......	21.46	16.94	17.07	18.49
7.	Raw bone meal............	200	21.72	16.17	16.14	18.01
8.	Thomas Slag phosphate.....	400	22.60	15.55	14.61	17.59
9.	(Complete fertilizer)					
	Nitrate of soda............	50				
	Dried blood...............	75				
	Acid bone meal............	250	20.63	14.57	15.18	16.79
	Sulphate of potash.........	50				
	Carbonate of potash in tobacco ashes............	75				
	(Complete fertilizer)					
10.	Nitrate of soda............	100				
	Dried blood...............	25				
	Acid bone meal............	250	22.35	16.49	15.99	18.28
	Sulphate of potash.........	50				
	Carbonate of potash in tobacco ashes............	75				

SUMMARY AND CONCLUSIONS.

(1) Colorado soils generally contain ample supplies of potash and phosphorus, and an excess of lime.

(2) The native soil is generally somewhat deficient in nitrogen and humus. Both are supplied by growing leguminous plants like alfalfa, peas, vetches, or beans, or from sheep and stable manures. Nitrogen, but not humus, can be supplied by commercial fertilizers.

Photo by courtesy "Sugar."

Planting sugar beets with four-horse teams and eight-row planters.

(3) Nitrogen in the form of nitrate of soda is the only element which has had any decided effect in increasing the yield of sugar beets over the cost of production.

(4) Potash and phosphorus, derived from sulphate of potash, raw bone meal, slag phosphate, acid bone meal, and phosphate rock, used alone or together, have very little or no effect on the yield.

(5) There are strong indications that potash and phosphorus from fertilizers, largely, if not entirely, neutralize the effect of nitrate of soda upon the yield of sugar beets, although the quality of the beet is good.

(6) No difference in results was obtained between applying the nitrate of soda at the time of planting, or in part at the time of planting, and in two applications during the growing season.

(7) The net profit from reasonable quantities of manure, if cost of application as well as cost of manure is considerable, is mainly obtained in the after effects in the succeeding year, while there appears to be no residual effect the third year after application.

(8) An excess of nitrogen from manures or fertilizer over what the plant needs lowers the yield and quality of the sugar beet some though not much.

(9) Reasonable quantities of manure were fully as effective as large or excessive quantities.

(13) Fertilizers will not take the place of good preparation or cultivation of the soil, or good care of the crop. The soil must be in good physical condition to make the best use of fertilizers applied.

PART IV

EXPERIMENTAL EVIDENCE

In this part there is briefly presented some of the most reliable and representative data on crop rotation that has been secured and published by the Agricultural Experiment Stations of the United States of America. The amount of scientifically collected data on this subject is comparatively small in proportion to the importance of the subject and the length of time crop rotation has been under discussion and in practice. American agricultural literature teems with opinions and observations on the subject, but comparatively little scientific investigation of crop rotation has been carried on for sufficient time and with sufficient thoroughness to provide extensive and reliable data.

In fact, the practice of crop rotation has developed in many places on the basis of erroneous beliefs in regard to its function in the problems of soil fertility, and in other places the value of the practice of crop rotation has been assumed as proven, and, therefore, the Experiment Stations have not investigated the subject very thoroughly nor with the idea of gathering real scientific data on the subject. Undoubtedly, in future years, there will be much more scientific data on the subject than now; for much experimental work has been started bearing on the problems of permanent soil productivity as well as on the business features of crop rotation in its relation to farm management. From such experimental work and data as are now available, however, selections have been made from the publications of the Minnesota, North Dakota, Nebraska, Illinois and Ohio Experiment Stations.

The investigations of the Minnesota, North Dakota and Nebraska Experiment Stations have been conducted with little regard for the use of commercial fertilizers, and are typical for a stage of agriculture that is midway between pioneer farming on rich, virgin lands, and intensive farming that must recognize some plant food deficiency in the soil. The data of the Minnesota, North Dakota and Nebraska Experiment Stations, as here given, are representative for, and applicable to, those soil regions that have an abundant reserve supply of plant food in the soil, and where there is especial need for systems of farming that will stimulate those processes of soil decay that will make available to crops these reserve supplies of plant food and at the same time provide a check on the direct outgo of the important elements of plant food. Under these conditions crop rotation, including legume meadows and pastures or legume green manures, and with forage crops fed to live stock, is sufficient to maintain productivity for many years to come, and there is rarely any need for the commercial fertilizer.

The crop rotation investigations of the Illinois and Ohio Experiment Stations have been conducted mainly in conjunction with commercial fertilizers to amend certain plant food deficiencies of the soil, and are typical for a stage of agriculture somewhat older than that of Minnesota, North Dakota, and Nebraska, and where the reserve supplies of plant food in the soil are somewhat lower—in some cases too low for profitable crop production, even though the best possible methods are provided for the liberation of available plant food from the reserve supplies in the soil. Under these conditions crop rotation is insufficient to maintain profitable yields and must be supplemented by soil amendment with fertilizers.

CHAPTER I

ROTATION AND FARM MANAGEMENT EXPERIMENTS—MINNESOTA

The crop rotation experiments at the Minnesota Agricultural Experiment Station were begun in 1894. The plans called for the continuous culture of the staple field crops of

Table VII. Yields of Wheat from Five Cropping Schemes. Average 6 Years 1899-1904.

(Table I, Bulletin 125, Minnesota Agricultural Experiment Station.)

Year.	Wheat continuously, no manure.	Two-year rotation: wheat and mangels, no manure.	Three-year rotation: corn wheat, clover, no manure.	Two-year rotation: wheat annual pasture, no manure.	Five-year rotation: corn, wheat, meadow, pasture, oats, 8 tons manure.
1899.......bushels	22.5	24.2	20.9	27.0	27.3
1900....... "	14.5	13.5	27.3	29.5	25.6
1901....... "	16.0	15.1	13.7	17.8	15.2
1902....... "	17.0	21.3	18.1	23.1	25.1
1903....... "	16.3	19.1	24.4	28.8	30.8
1904....... "	20.8	20.0	27.3	28.6	32.0
Average yield "	17.8	18.9	21.9	25.8	26.0
Average value "	$11.80	$12.41	$14.76	$16.99	$17.44
Gain in yield over continuous wheat, bushels..........	....	1.1	4.1	8.0	8.2
Gain in value over continuous wheat	....	$0.61	$2.96	$5.19	$5.64

NOTE: The average value of the crops is based on a ten year average, December 1st farm price for crops, as recorded in the Yearbook of the United States Department of Agriculture.

Minnesota, and rotations of these crops in various combinations, with and without legume crops, and in long and short rotation cycles. At the time these experiments were made there was no interest in the use of commercial fertilizers in Minnesota and no fertilizer work was included in these experiments. The plots of land were analyzed and special study was made of the effect of continuous and rotation cropping on the soil's supply of nitrogen and humus.

This experimental work at the Minnesota Station is especially valuable in making comparisons between the cost per acre of continuous and rotation cropping. The Minnesota Experiment Station has accumulated many reliable and scientific data on the subject of "costs of farming" that

Table VIII. Comparisons of Yields of Corn Grown Continuously with Corn Grown in Three and Five-Year Rotations for Five Years.

(Table II, Bulletin 125, Minnesota Agricultural Expt. Station.)

Year.		Corn continuously, no manure	Corn in 3-year rotation: corn, wheat, clover no manure	Corn in 5-year rotation: corn, wheat, meadow, pasture, oats, manure
1899	bushels	20.8	51.1	31.3
1900	"	37.5	42.6	58.0
1901	"	13.9	42.0	42.8
1903	"	23.6	54.7	85.3
1904	"	11.1	45.1	37.1
Average, 5 years	"	21.4	47.1	50.9
Average value		$7.01	$16.11	$17.89
Gain in yield over continuous cropping		bushels	25.7	29.5
Gain in value over continuous cropping			$9.10	$10.88

Record of crop of 1902 lost.

are used to advantage in comparing the merits of continuous and rotation cropping. These rotation experiments are of value in studying effects of continuous and rotation cropping on the nitrogen and humus content of the soil.

The most important features of this experimental work relative to crop rotation and soil fertility are given herewith.

Table IX. Comparisons of Very Good and Very Poor Cropping Schemes.

(Table IV, Bulletin 125, Minnesota Agricultural Experiment Station.)

Series.	Plat.	Rotation scheme	Annual net profit per acre (+) or net loss (—), 1900–1909	Loss or gain of nitrogen, 1895–1904	Loss or gain of carbon, 1895–1904	When manured
		Group 1. **Very good cropping schemes**		*Per cent*	*Per cent*	
I	9	1, wheat; 2, 3, meadow; 4, oats; 5, potatoes	+$8.11	+0.008	....	1899,1904,1909
IV	10	1, wheat; 2, 3, meadow	+ 7.40	+ .011	+0.16	
IV	8	1, barley; 2, 3, 4, pasture; 5, corn	+ 6.41	+ .016	....	1899, 1905.
IV	5	1, corn; 2, rye and rape; 3, barley; 4, pasture	+ 6.03	+ .022	....	1900,1904,1908
		Standard rotation, check plats, series I, II, III, IV, plat 1, 6, 11; 1, corn; 2, wheat; 3, 4, meadow; 5, oats	**+ 5.87**	**+ .015**	**+ .09**	**1899,1904,1909**
II	4	1, barley; 2, oats; 3, 4, timothy	+ 5.82	....	+ .15	
III	7	1, wheat; 2, permanent pasture	+ 5.36	+ .004	+ .07	
		Group 2. **Very poor cropping schemes**				
II	7	Corn in hills continuously	— 1.47	— .040	— .54	
III	9	1, millet hay; 2, clover; plow under second crop	— 2.03	+ .007	....	
III	10	Rape continuously; drill; pasture off	— 2.40	....	+ .10	
II	8	Potatoes continuously	— 3.17	— .034	— .66	
II	9	Mangels continuously	— 14.55	— .033	— .45	

Note: The average, annual net profit or net loss per acre shown in this table is arrived at by giving each crop a gross value based on average December 1st farm prices for crops shown by the Yearbook of the United States Department of Agriculture, and subtracting therefrom the average cost of producing the crop as shown in Bulletin 117 of the Minnesota Experiment Station and page 490 of this book. These figures represent the genuine net profit or net loss. All production costs were considered, including $3.50 per acre for land rental or interest on the land value.

It may be noted from this table that the rotation schemes of cropping not only yielded greater net profits than the schemes of continuous cropping, but also maintained or increased the humus and nitrogen content of the soil, whereas, nitrogen and humus decreased under the schemes of continuous cropping, particularly with a continuous succession of cultivated crops.

Table X. Comparative Yields of Corn, Wheat, and Hay under Different Systems of Cropping. 1899-1907.

(Table IX, Bulletin 125, Minnesota Agricultural Experiment Station.)

Year	Corn			Wheat			Hay	
	Corn continuously	Corn in 3-year rotation	Corn in 5-year rotation	Wheat continuously	Wheat in 3-year rotation	Wheat in 5-year rotation	Hay in 3-year rotation	Hay in 5-year rotation
	Bushels	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Tons*	*Tons*
1899	20.8	51.1	31.3	22.5	25.3	27 3	......	......
1900	37.5	42.6	58.0	14.5	27.3	25.6	......	......
1901	13.9	42.0	42.8	16.0	13.5	15.2	1.58	2.36
1902	[1]	62.0	78.6	17.0	18.1	25.1	2.25	1.95
1903	23.6	54 7	85.3	16.3	24.4	30.8	3.86	6.10
1904	11.1	45.1	37.1	20.8	27.3	32.0	4.26	5.77
1905	25 1	64.1	64.4	20.8	20.6	30.9	4.86	5.81
1906	27.6	36.1	60 5	14 1	13.3	22 6	1.91	3.18
1907	23 6	35.2	52 2	24.5	19.1	23 9	1.25	1.42
Average, 9 years	[2]22.9	48.1	56.7	18.5	21.0	25 9	[3]2.85	[3]3.80
Gain	......	25.2	33.8	....	2 4	7 4	.....	.95

[1] Record lost. [2] Eight years. [3] Seven years.

Note: The plats continuously planted to one crop and the 3-year rotation plats were not manured. The 5-year rotation plats received 8 tons of manure every fifth year.

Table XI. A Comparison between Continuous Cropping and Rotation Cropping at the Minnesota Agricultural Experiment Station. Average Yields 10 Years, 1902-1911.

Systems of Cropping	Wheat	Corn	Oats	Hay	Mangels
	Bushels	*Bushels*	*Bushels*	*Tons*	*Tons*
Wheat, continuously	19.3	....	....	....	....
Corn, continuously	....	(a) 27.5	....	....	....
Hay, continuously	....	....	....	(b) 1.7	....
Mangels, continuously	....	....	....	....	3.8
(c) Wheat, continuously... 6 lbs. red clover annually	22.1	....	....	....	....
2-year rotation, wheat and mangels	23.4	....	....	....	9.2
2-year rotation, wheat and annual pasture	27.0	....	....	....	....
3-year rotation, wheat, clover and corn	20.6	46.3	....	(a) 2.7	....
5-year rotation, wheat, meadow, pasture, oats, and corn	27.4	61.3	58.6	(b) 3.6	....

NOTE: (a) Nine-year average. (b) Eight-year average. (c) Clover plowed under in the autumn.

No manure was used on any fields except eight tons per acre applied to the corn crop in the five-year rotation.

The rotations were started in 1894. Yields are for the ten-year period 1902 to 1911.

This table prepared by, and published through the courtesy of, Prof. Andrew Boss, Chief of the Division of Agronomy and Farm Management, Department of Agriculture, University of Minnesota.

Summary of Rotation Experiments. (Bulletin 125, Minnesota Agricultural Experiment Station.)

(1) Cultivated crops, as corn, potatoes, and mangels, grown continuously, rapidly decrease the productivity of soils. This is largely due to the fact that cultivation stimulates decomposition of vegetable matter, leaving too small a supply of fresh vegetable matter in the soil.

(2) Grain crops grown continuously decrease the productivity of soils. This, it is believed, is in part due to reducing the fresh vegetable matter which supports chemical

From Bul. 125, Minnesota Agr. Expt. Station.
Corn on a plot growing corn continuously. Average yield for the last ten years of an eighteen year period of time 27.5 bushels per acre.

and wholesome bacterial activity in the soil, and in part due to an increase in weeds.

(3) A rotation of corn, oats, millet, and barley, which tend to exhaust the supply of vegetable matter, did not produce better results than continuous wheat cropping.

(4) A 2-year rotation of mangels and wheat, both of which reduce vegetable matter, gave little better yields of wheat than wheat continuously.

(5) A 2-year rotation of wheat and annual pasture gave greatly increased yields of wheat, presumably in large part because the annual pasture crop added fresh vegetable matter to the soil, greatly increasing the bacterial and chemical activities of the soil and improving its physical condition.

(6) A 3-year rotation of corn, wheat, and clover with no manure did not give as large yields of corn and wheat as were obtained from a 5-year "standard" rotation of corn, wheat, meadow, pasture, and oats, with some manure applied to the corn. The lower yield on the 3-year rotation is pre-

From Bul. 125, Minnesota Agr. Expt. Station.

Corn on a plot growing corn in a five-year rotation of corn, wheat, clover and timothy meadow, pasture, and oats. Eight tons of barnyard manure applied every five years. Average yield for the last ten years of an eighteen year period of time 61.3 bushels per acre.

sumably due mainly to the fact that clover once in three years did not maintain the supply of fresh vegetable matter so fully as did the 5-year rotation with two grass crops and 8 tons of manure once every five years.

(7) Among the advantages of vegetable matter in the soil the following may be named: It aids aeration, retains moisture, deepens the soil, prevents baking, checks leaching and washing, stimulates decomposition, supplies easily usable plant food, affords favorable conditions for bacteria, increases chemical activities, and presumably aids in disposing of or neutralizing substances left by crops which are evidently toxic to the same or to other crops.

(8) The combination of cultivated crops, grain crops, and grass crops, including clover, as in the 5-year standard rotation, not varying greatly from two fifths of the time in grass, results in substantial profits.

(9) In a word, the best rotation schemes yield $12 to $16 worth of crops, at a cost, including $3.50 rental, labor, and all other expenses, of $7 to $11. With a net profit of $3 to $6 per acre, and under the conditions of the average farm there should be secured a net profit of $2 to $4 per acre on all the cultivated acreage.

Influence of Crop Rotation and Continuous Cultivation upon the Composition and Fertility of Soils. (Bulletin 109, Minnesota Agricultural Experiment Station, pp. 286, 332, 334, 335, 336.) On most Western farms it is more economical at the present time to make the reserve mineral matter available as plant food than to purchase new stores. In many soils there is a large amount which is not in the most available forms, but is capable of being made so by cultivation. It should be the aim to keep this reserve fertility in such a condition that it will gradually become available and can be drawn upon by future crops. When the soil is made to produce one crop year after year, there is but little opportunity for the reserve fertility to become available. * * *

* * * Chemical and physical changes are continually taking place in the soil, and in some soils these changes are more rapid than in others. In the cultivation of the soil it should be the aim to assist nature in bringing about those changes which render the plant food available.

* * * While a rotation of crops in which clover forms an essential part may result in maintaining the nitrogen and humus content, there is, after a series of years, a material loss of mineral plant food, as potash and phosphorus compounds. In fact, a rotation of crops removes more total mineral plant food from the soil than when a grain crop is grown continuously, and thus a rotation may hasten the exhaustion of fertility. A rotation of crops with the occasional use of farm manures and the production of clover will not indefinitely maintain the fertility of all soils; only those soils that are naturally fertile and contain large amounts of reserve plant food will indefinitely respond to such a system of cropping. * * *

Table XII. Rotation Removes More Mineral Plant Food Than Continuous Cropping to Wheat.

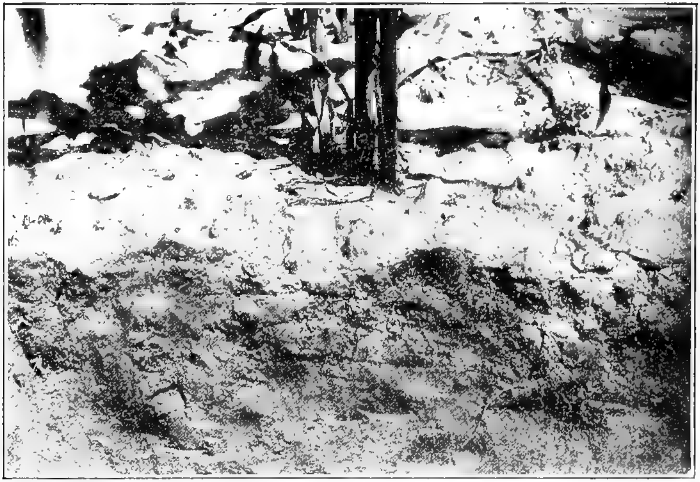
(Table XLI, Bulletin 109, Minnesota Agricultural Experiment Station.)

FIVE-YEAR ROTATION SERIES III. PLOT 1			FERTILITY REMOVED		
Year	Crop	Yield	Nitrogen	Phosphorus	Potassium
1900	Wheat	23.3 bu.	40.8 lbs.	10.17 lbs.	33.9 lbs.
1901	Meadow	3.2 tons	....	33.53 lbs.	147.4 lbs.
1902	Meadow	2.1 tons	....	22.00 lbs.	96.5 lbs.
1903	Oats	59.0 bu.	59.0 lbs.	9.25 lbs.	44.1 lbs.
1904	Corn	58.3 bu.	96.8 lbs.	11.26 lbs.	64.2 lbs.
Total fertility removed in five years......................			196.6 lbs.	86.21 lbs.	386.1 lbs.
Fertility added by 8 T. manure..			81.6 lbs.	24.45 lbs.	67.7 lbs.
Total lost by rotation...........			115.0 lbs.	61.76 lbs.	318.4 lbs.
WHEAT CONTINUOUSLY SERIES III. PLOT 2.					
(Total Yields 1900 to 1904 inc. 84.6 bu.)					
Total fertility removed in five years			148.0 lbs.	36.94 lbs.	122.8 lbs.
Excess removed by rotation.....			*–33	24.82 lbs.	195.6 lbs.

NOTE: The figures for determining the amount of fertility removed by the various crops were taken from Prof. Snyder's "Soils and Fertilizers." The figures for determining the amount of plant food supplied by the manure were taken from Cornell Bulletin No. 27.

No nitrogen is charged against the meadow crops as the crop was about one half timothy and one half clover, and it is assumed that the clover added as much nitrogen as both crops removed.

* * * The indiscriminate practice of bare summer fallowing has been another cause of loss of the soil's nitrogen

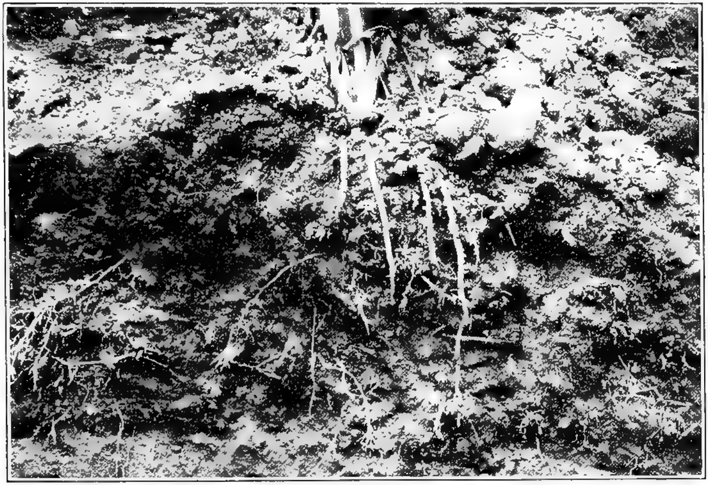


From Bul. 125, Minnesota Agr. Expt. Station.

Vertical section of soil on a plot that has grown corn continuously for eighteen years. Note the absence of vegetable matter and the hard, compact, gritty appearance of the soil.

and humus. The occasional fallowing of land to destroy insect pests and weed seed is often necessary, but the alternation of grain and summer fallowing is particularly destructive to the humus by encouraging rapid decay with liberation of the nitrogen. Fallowing is temporarily beneficial, a few good crops being secured, but it is at the expense of permanent fertility. Experiments show that when summer fallowing is practiced five times more nitrogen is rendered soluble and available than is required for the succeeding crop; and the soluble nitrogen that is not utilized as plant food is readily lost. There is no soil so rich in nitrogen that it can endure the long continued practice of summer fallowing without ultimate decline in fertility.

Particular stress is laid upon the nitrogen and humus of the soil, because they may be controlled by cultivation, and, if the humus and nitrogen content is maintained, the problem of fertility is greatly simplified. The maintenance



From Bul 125, Minnesota Agr. Expt. Station.

Vertical section of soil near a corn plant growing on newly broken alfalfa sod. Note the presence of vegetable matter, and the loamy, friable appearance of the soil.

of the mineral plant food of the soil cannot be neglected; but the mineral matter is not subject to such large gains and losses as the nitrogen. * * *

* * * On some soils the rotation of crops only hastens exhaustion of the fertility by causing a larger total amount of plant food to be removed, and where large reserves do not exist in the soil the use of commercial fertilizers will be necessary. At the present time and in the case of prairie soils that are beginning to show the effects of excessive grain production, rotation of crops and the production of clover will be more beneficial than any other means for restoring fertility. This will assist in securing larger yields for a series of years, but will not prove the final solution of the problem of maintaining the fertility of the soil. * * *

* * * Commercial fertilizers should not be used indiscriminately on old soils with a view of securing large yields,

and it is not feasible by their use alone to economically restore the fertility to soils that have been impoverished by exclusive cropping to small grains. Commercial fertilizers are of great value when judiciously employed in a rotation and for encouraging the growth of legumes, as clover, so as to add nitrogen to the soil from atmospheric sources. It is believed that when they are used in this way they will prove beneficial and remunerative. Before applying them in large amounts it is recommended that farmers make preliminary trials on a small scale to determine the actual needs of the soil, so that unnecessary elements of plant food be not purchased. Commercial fertilizers cannot take the place of farm manures or crop residues, particularly those from clover and timothy, for permanently improving the soil; but they aid in the production of some crops and often assist a crop, as clover, which in turn is beneficial in adding nitrogen and humus to the soil.

Commercial fertilizers should be used in connection with crop rotations, farm manures, and clover production, rather than as the only means of increasing the fertility. When judiciously used, they have a proper place in our agriculture; but when indiscriminately applied, there is generally a financial loss.

CHAPTER II

CROPPING SYSTEMS FOR WHEAT IN NORTH DAKOTA

The crop rotation experiments of the North Dakota Agricultural Experiment Station were begun in 1892, and the original plans were discontinued in 1907 to make way for a new group of rotation experiments better adapted to diversified types of farming and the present agricultural conditions of North Dakota. The experimental data here quoted were gathered during the period 1892 to 1907 while the agriculture of North Dakota was quite young and when wheat culture was the universal farm enterprise of the state.

These data are of particular interest to students of soil fertility, crop rotation, and permanent systems of farming, because they illustrate certain elementary principles in the maintenance of soil productivity, such as the value of inter-tilled crops in rotation with thickly sown grain crops, and also the value of humus producing, nitrogen gathering legume crops in rotations with thickly sown grain crops. These experiments are also interesting in that they illustrate the rapid changes that take place in the soil of a new agricultural region after the pioneer days are over. Evidently the experiments were planned to prove to an unbelieving population of continuous wheat growers the vital and fundamental facts about soil productivity. Wheat was included prominently in all the rotation plans, and the plans were so projected as to show the influence of inter-tilled crops, animal manures, green manures, and bare fallow on the yield of wheat. These experiments illustrate the elementary facts about soil productivity very nicely and show how quickly in the history of a rich soil area the available stores of virgin fertility are taken up by crops, and how quickly the need

arises for cropping systems that will somewhat check the sale of plant food from the soil and liberate supplies of available plant food from the reserve supplies in all naturally fertile soils.

The most striking features of the cropping system experiments of the North Dakota Agricultural Experiment Station are herewith quoted from Bulletin 100 of that Station (pp. 5, 6, 7, 8, 25, 31, 32, 33, 34, 35, 37, 38, 41, 42, 43, 44, and 45.)

Table XIII. Composition of Typical Soils of the Red River Valley in North Dakota.

Pounds per Acre in Two Million—about 7 Inches of Soil. (Table I, Bulletin 100, North Dakota Agricultural Experiment Station.)

Locality	Total Nitrogen	ACID SOLUBLE	
		Phosphorus	Potassium
Bathgate	7,560	1,460	11,560
Fargo	7,200	2,520	13,600
Wahpeton	5,520	1,040	6,540
(Average)	6,760	1,673	10,566

NOTE: These samples were taken from fields that are representative of the Red River Valley. It is evident that these soils are well supplied with the important elements of plant food. That the black soil of the Red River Valley contains a comparatively large amount of the important elements of plant food is evident. The soils used in making these analyses have been cropped in much the same manner as the average farm in the Red River Valley. At the time the sample was taken at Fargo the land had grown at least nineteen successive crops of wheat. The other samples were taken from land that, previous to its use as a demonstration farm, had been cropped by farmers without any special effort to maintain its fertility. In their virgin state these soils would have no doubt shown a higher percentage of the important elements than some of the most productive lands of the corn belt.

It is evident, therefore, that our problem is not one of building up worn out lands, but of making the best use of an adequate supply of plant food supplementing it as much as possible with manures in order that this supply may be maintained for future production. Briefly this will be accomplished by through tillage, drainage, proper rotation of crops and the rational use of manures.

* * * The original purpose of these crop rotation experiments was to determine the influence of various crops, and the cultivation incident to their production, upon the yield of succeeding crops of wheat. For this reason wheat is the most prominent crop in all of the rotations. * * *

* * * These experiments were conducted on a nearly level forty acres of typical Red River Valley land having fair surface drainage provided by roadside ditches. The land was exceptionally uniform in physical texture as well as in chemical composition as revealed by analyses. The land was broken about 1882 and had borne continuous crops of wheat until 1892.

Table XIV. Average Yields of Wheat on Plots Cropped Continuously and in Rotation.

(Table V, Bulletin 100, North Dakota Agricultural Experiment Station.)

Yield per acre of all plots continuous wheat Average 12 years	Average yield per acre all plots in rotation Average 15 years	Increase due to rotation
13.13 bu.	19.12 bu.	5.99 bu.

The Influence of Corn in Rotation with Wheat. It is quite generally recognized that the cultivation given the corn crop improves the physical, chemical and biological relations of the soil so that it is in better condition for wheat production. In order to get at the benefits measured by crop yield, plots 5 and 6 (as shown in the following table) were cropped to corn one year followed by three years of wheat. Plot 6 received an application of six loads of rotten manure per acre. No application of manure was made to plot 5. The yields for these two plots are summarized and compared with the yields on plot 2 which has been in wheat continuously during the period. The yields for the first year and the second year after corn are the average of four crops, and the yields the third year after corn are the average of three crops.

Table XV. The Influence of Corn on Succeeding Wheat Yields.

(Table VIII, Bulletin 100, North Dakota Agricultural Experiment Station.)

Plot	Wheat after	1st Year after		2nd Year after		3rd Year after	
		Bushels Yield	Bushels Increase	Bushels Yield	Bushels Increase	Bushels Yield	Bushels Increase
2	Wheat	11.27	....	15.39	....	19.40	....
5	Corn	19.14	7.87	22.96	7.57	21.80	2.40
6	Corn	20.48	9.11	25.85	10.46	25.78	6.38

Note: The highest yields were obtained the second year after corn. This group of years was somewhat more favorable for wheat production than either of the other two, but the yields on the continuous wheat plot indicate that the first group of years was by far the most unfavorable. The real test of the influence of the corn, however, is measured by the increase in yield over continuous wheat. The significant facts brought out by the above data are as follows:

(1) The culture of corn increased succeeding wheat yields.

(2) The benefit of the corn crop is greatest in the two years immediately succeeding the year in which it is grown.

(3) An application of farm manure once in four years increases the yields of wheat in a rotation with corn.

(4) The beneficial effects of such manuring extended over a longer period than the effects of corn in the rotation.

The Influence of Potatoes in Rotation with Wheat. The culture given potatoes is quite similar to that given corn and as potatoes can be marketed directly to better advantage than corn in this locality, providing there is a shipping point close at hand, some farmers prefer to raise them as a cultivated crop. In order to determine the effect of potato culture on succeeding wheat yields, a rotation consisting of potatoes one year and wheat three years was started on plot 20 in 1896. Plot 19 was originally planned to be seeded to wheat continuously and was continued as such until 1900. Comparisons can, therefore, be made between these two plots for one four-year period.

Photo by courtesy N. S. Davies, Red River Valley Development Association.
In the northern part of the North Central states potatoes are an important "cultivated crop." The potato crop fits the land in fine shape for small grain and is of great assistance in controlling weeds.

Table XVI. The Influence of Potatoes on Succeeding Wheat Yields.

(Table IX, Bulletin 100, North Dakota Agricultural Experiment Station.)

Plot	Wheat after	First Year Bushels per Acre	Second Year Bushels per Acre	Third Year Bushels per Acre
19	Wheat	18.30	17.28	17.48
20	Potatoes	16.80	30.57	21.65
Increase or Decrease		−1.50	+13.29	+4.17

NOTE: While the period during which this work was conducted was too short to draw any definite conclusions, it is evident that the introduction of potatoes into the rotation has a marked beneficial

effect on wheat yields. As was the case with corn, the beneficial effects were not as marked the third year after potatoes were grown as the second year.

The Influence of Field Peas in Rotation with Wheat. It is often desirable and sometimes necessary to replace a biennial or perennial legume with an annual legume. The latter fit into short rotations a little better and, as a rule, it is comparatively easy to secure a stand. If, for any reason, a stand of clover is not obtained the previous year, the land must be seeded to an annual legume, if the rotation is to be maintained without interruption. For the Northwest, field peas have proved to be the most satisfactory legume crop. In order to determine the influence of field peas on wheat yields, a rotation consisting of peas one year and wheat three years was carried out on plots 7 and 8. The pea crop was removed from plot 7, and plowed under on plot 8. The following table shows a comparison of the yields of these plots with those on plot 2, the continuous wheat plot for the same year.

Table XVII. The Influence of Field Peas on Succeeding Wheat Crops.

(Table XII, Bulletin 100, North Dakota Agricultural Experiment Station.)

Plot	Wheat after	First Year		Second Year		Third Year	
		Bushels Yield	Bushels Increase	Bushels Yield	Bushels Increase	Bushels Yield	Bushels Increase
2	Wheat	11.27	....	15.39	....	19.37	....
7	Peas	17.80	6.53	17.32	1.93	19.08	—0.29
8	Peas	15.91	4.64	19.49	4.10	21.73	2.36

Note: The turning under of the pea crop failed to produce an increase in wheat yield the first year after, but there was a gain of 2.17 bushels the second year, and 2.65 bushels the third year attributable to the green manuring. A study of this data indicates that green manuring with field peas does not give immediate results in a soil well supplied with organic matter, but that, when such manuring

is practiced regularly, the beneficial effects are cumulative. In the last half of the period the yield on the green manured plot was greater than on that from which the peas were removed. The plot from which the peas were removed showed an increase in yield over the continuous wheat plot the first and second years, but the beneficial effects did not extend to the third crop of wheat following.

The Influence of Summer Fallow on Succeeding Wheat Yields. One of the greatest impediments to the continuous production of wheat on the same land is the rapid increase of certain weeds due to the carrying over of the seed from one year to another. In the past, summer fallow has been one of the most common methods of cleaning the land of weeds in this state. In order to determine the influence of fallow on succeeding wheat crops, plots 4, 15 and 26 were fallowed every fourth year and seeded to wheat the three remaining years. * * * A comparison of the yields of the first, second and third wheat crops after fallow with continuous wheat is given in the following table.

Table XVIII. The Influence of Fallow on Succeeding Wheat Crops.

(Table XIV, Bulletin 100, North Dakota Agricultural Experiment Station.)

Plot	Wheat after	First Year		Second Year		Third Year	
		Bushels Yield	Bushels Increase	Bushels Yield	Bushels Increase	Bushels Yield	Bushels Increase
2	Wheat	11.27	....	15.39	....	19.37	....
4	Fallow	16.93	5.66	22.26	6.87	27.30	7.93
15	Fallow	20.89	9.62	18.51	3.12	22.53	3.16
26	Fallow	16.55	5.28	19.00	3.61	21.08	1.61

NOTE: Plots 4 and 26 were plowed twice and plot 15 was plowed but once, in July. The extra plowing in the fall failed to produce an increase in yield of the wheat crops, as indicated by the difference between plots 15 and 26. The yields of plot 4 are not strictly comparable on this point, because the fallow was manured with six loads of rotten manure on this plot. The same general tendency of the yields to be maintained after fallow for a longer period, when manured as

was noted when corn was manured in the rotation, is evidenced in the data. The figures indicate that fallow produces a marked increase in yield the first and second years and to a lesser degree in the third year after having been fallowed. It is usually considered, however, to be more economical to have corn take the place of fallow on account of the income received from the corn crop.

The Relation of Active Organic Matter in the Soil to Wheat Yields. The soils of the Red River Valley are very high in their content of organic matter, but some of these have been cropped for some time without the return of organic manures, and the greater part of this organic matter is in the more advanced stages of decay. In this form it decays very slowly and has only a slight effect on the availability of the mineral elements of plant food in the soil.

There are two plots in Series I. which show the effect of farm manure applied once in a four-year cropping system. As an average, manure has produced an increase in the yields of all crops on each of these plots. * * * The most satisfactory method for calculating this increase is on the percentage basis.

Table XIX. The Increase in Wheat Yield Due to Farm Manure, by Courses, 1892-1906.

(Table XVIII, Bulletin 100, North Dakota Agricultural Experiment Station.)

Plot	Manure applied to	Per Cent Increase			
		1st Course	2nd Course	3rd Course	4th Course
6	Corn	5.5	9 3	21.5	(*) 12.5
10	Millet	6.1	10.1	33.0	(*) 30.2

(*) Three year period only.

NOTE: There has been a gradual rise in the percentage of increase as the years have advanced with the exception of the last course. In this case, however, the yields of wheat for only two years are available and in one of these years (1905) the rainfall was the highest that has been recorded at the Experiment Station. It is a well established fact that manure does not show as much beneficial effect in wet years

as in dry years, hence very little increase would be expected on the clay soil of the Red River Valley in a year that the rainfall was 17.22 inches in April, May, June and July, as was the case in 1905. As 1906 was not an especially favorable year for wheat the yields were low and the increase less striking. If the third wheat crop in this course had been harvested, the increase might have been as great as in the third course.

In the past very little attention has been given to the production, management and use of farm manures on many of the farms of the state. The manure produced by the work stock has been allowed to accumulate and remain exposed for years and the greater part of its fertilizing value lost. The failure to appreciate the value of manure has been largely due to the fact, that, under our climatic conditions, organic manures do not decay rapidly enough to show marked results the first year or so.

Another mistake has been made in plowing under fresh manure for small grain. The manure should be applied when fresh to pasture land which is to be broken, or should be plowed under for corn which is to be followed by small grains. It is thus given a chance to decay in the soil before the land is seeded to small grains.

It is quite evident that the maintenance of the supply of organic matter has a very important bearing upon wheat production and that, while the yield is increased the first few years to a marked degree, the yields are more striking as the years advance, indicating that the results are cumulative and extend over a period of years.

Futhermore, in the early years of the experiment the soil contained a high percentage of native organic matter in the early stages of decay and hence did not respond to the manure as much as it did later when this natural supply had been materially reduced by cropping.

Two plots in this series furnish us data relative to the effect of green manure upon the yield of wheat. The field peas which were seeded on plot 8 every four years were plowed under for green manure, and the millet, occupying a similar place in the cropping system on plot 11, was plowed under. By comparing the yields on these plots with those on plots 7 and 9 (similar rotations including peas and millet,

but with all crops removed from the land) the increase due to the green manuring can be calculated. The increase expressed in percentage is given herewith.

Table XX. The Influence of Green Manuring on Wheat Yields by Courses, 1892-1906.

(Table XIX, Bulletin 100, North Dakota Agricultural Experiment Station.)

Plot	Green Manured with	Per Cent Decrease or Increase			
		1st Course	2nd Course	3rd Course	4th Course
8	Field Peas	—9.6	—6.9	+33.2	+17.6
11	Millet	+ .6	—7.0	+10.0	+10.5

NOTE: If we consider the first two courses only, green manuring has been a failure, but the later data shows it to be of marked benefit. In fact, the increase of the last two courses has more than offset the decrease in the first two.

It is evident that the soil was so high in native organic matter in the early years that the artificial supply was unnecessary. As the years advanced, however, the original supply became depleted rapidly and an increase in yield resulted from the residual effects of the green manures plowed under in the early years of the experiment.

Under our climatic conditions plant tissues decay rather slowly and, when plowed under in large amounts, they separate the plowed soil from the lower soil layers for some time. When the soil is plowed early in the fall and seeded to wheat early in the spring, not enough tillage is given to fill all of the open spaces between the plant stems and effect capillarity. As a result, many of the wheat plants on such land suffer from lack of water even in periods of moderate drouth. This could be avoided if a cultivated crop like corn, potatoes or other roots, were planted the first year after the green manuring. The soil is prepared for these crops later in the spring and the inter-tillage given them extends well into the summer. More water is conserved in the soil by this means and the open spaces between

the plant stems are filled in with soil. The result is that they decay more rapidly and the re-establishment of normal movement of soil water is more immediate.

Green manuring with field peas has produced a larger average increase than with millet. This is probably due in part to the higher nitrogen content of the peas, part of which is obtained from the atmosphere. There is some addition of organic matter to the soil when millet is plowed under, but all of the nitrogen in the millet crop has been obtained from the soil, and hence there is no actual addition of this element. The continued green manuring with millet or any non-legume would produce soil organic matter of a low nitrogen content. As time advances, it would be necessary for decay to take place more rapidly in order to produce enough nitrogen to meet the demands of a maximum crop. While nitrogen is probably not as yet a limiting factor on the soils of the Red River Valley, their native supply has been materially reduced and some attention should be given to its maintenance by the application of manures and the placing of legume crops in the rotation.

CHAPTER III

CO-OPERATIVE ROTATION AND FERTILIZER TESTS—NEBRASKA

(Bulletin 122, Nebraska Agricultural Experiment Station p. 6).

* * * * * * * Reports from thirty-one Nebraska farmers from 1906 to 1908 show that they had an average yield of 34.5 bushels of corn per acre on land before seeding it to clover and alfalfa, and 68.2 bushels when the field was plowed up and again planted to corn. Co-operative fertilizer tests carried on by this department on Nebraska farms show that the plots which were not treated averaged 25 bushels of corn per acre, while the ones to which barnyard manure had been added gave an average yield of 36.5 bushels. * * *

CHAPTER IV

CONTINUOUS AND ROTATION CROPPING, WITH AND WITHOUT MANURE OR COMMERCIAL FERTILIZERS—OHIO

Experimental field evidence from the Ohio Experiment Station, at Wooster, relative to the maintenance of soil fertility, is the most complete and authentic of any available in the United States. The work was started in 1893 and the investigational data herewith given covers periods of time from fifteen to twenty years.

In the accompanying tables and notes the figures are taken exactly from the published reports of the Ohio station, although some rearrangement has been made for the sake of conciseness and popular presentation.

Table XXI. Crops Grown in Continuous Culture with and without Fertilizers. Average Annual Yields and Increases Due to Fertilizers. 19 Years, 1894 to 1912.

(Table 1, Circular 131, Ohio Agricultural Experiment Station.)

Plot No.	Fertilizing Materials, Pounds per Acre	Yield Per Acre		Increase Per Acre	
		Bus. Grain	Lbs. Stover or Straw	Bus. Grain	Lbs. Stover or Straw
	CORN				
	Average of 4 plots unfertilized	15.88	1245	......	......
2	Acid phos. 160; muriate of potash 100; nitrate of soda 160	42.09	2346	22.65	972
5	Yard manure 2½ tons	27.67	1781	12.21	547
6	Yard manure 5 tons	37.64	2154	22.51	933
8	Acid phos. 160; muriate of potash 100; nitrate of soda 320	47.24	2431	33.50	1282

OATS

	Average of 4 plots unfertilized........	22.92	921	......	......
2	Acid phos. 160; muriate of potash 100; nitrate of soda 160................	41.41	1949	20.31	1124
5	Yard manure 2½ tons..............	30.80	1274	7.65	347
6	Yard manure 5 tons................	38.29	1821	14.71	862
8	Acid phos. 160; muriate of potash 100; nitrate of soda 320...............	47.39	2497	23.77	1506

WHEAT

	Average of 4 plots unfertilized........	7.52	938	......	......
2	Acid phos. 160; muriate potash 100; nitrate soda 120; dried blood 50....	19.05	2474	11.48	1458
5	Yard manure 2½ tons..............	13.33	1699	5.47	744
6	Yard manure 5 tons................	17.41	2212	9.59	1250
8	Acid phos. 160; muriate potash 100; nitrate soda 280; dried blood 50....	21.96	2858	14.45	1931

NOTE: The increase in yield of the fertilized plots over the unfertilized plots has been computed by the Ohio Agricultural Experiment Station on the assumption that changes in the natural fertility of the soil in experimental fields are likely to be progressive, that is to say; that if the yields of plots 1 and 4 unfertilized were 30 and 33 bushels respectively, the yields of plots 2 and 3 would probably have been 31 and 32 bushels respectively, had no fertilizers been applied. Thus in these tables showing increased yield of fertilized plots over unfertilized plots, the increase shown is not computed by making a comparison of the yield of each fertilized plot with an average of yield from all unfertilized plots, but is computed by means of a comparison with adjoining unfertilized plots that aims to eliminate all differences in yield caused by variations in the natural fertility of the soil. This method of computing increase in yields is followed in all reports on crop yields from this Experiment Station.

This table does not show the complete records for continuous crop culture, with and without fertilizers, at the Ohio Experiment Station. In order to simplify the comparisons the two highest yielding fertilized plots and the plots fertilized with barnyard manure have been selected to compare with continuously cropped plots without fertilizers.

The fertilizing materials are valued at a fraction over $16.00 per ton for acid phosphate; 2½ cents per pound for muriate of potash; and 3 cents per pound for nitrate of soda.

Table XXII. Crops Grown in 5-Year Rotation of Corn, Oats, Wheat, Clover and Timothy, and Clover and Timothy. Average Annual Yields with and without Fertilizers. 19 Years 1894-1912. (Table IV, Circular 131, Ohio Agricultural Experiment Station.)

Plot No.	Fertilizing Materials in Pounds per Acre for Each Rotation	Corn		Oats		Wheat		Hay	
		Bus. Grain per Acre	Lbs. Stover per Acre	Bus. Grain per Acre	Lbs. Straw per Acre	Bus. Grain per Acre	Lbs. Straw per Acre	Lbs. Clover per Acre	Lbs. Timothy per Acre
	Average Yield of 10 Plots Unfertilized	**29.74**	**1668**	**31.00**	**1300**	**10.21**	**1045**	**1883**	**2651**
2	Acid phosphate 320	37.83	1871	40.73	1683	18.12	732	2510	3123
5	Nitrate soda 440; dried blood 50	34.65	1822	35.17	1418	12.31	1365	2341	3139
8	Acid phosphate 320; muriate potash 260	44.09	2177	42.45	1881	19.40	1850	2902	3122
9	Muriate potash 260; nitrate soda 440; dried blood 50	36.16	1941	37.35	1670	13.06	1396	2320	2987
11	Acid phosphate 320; muriate potash 260; nitrate soda 440; dried blood 50	47.47	2284	50.09	2283	26.22	2791	3312	3583
14	Acid phosphate 240; muriate potash 180; nitrate soda 280; dried blood 50	44.44	2188	39.44	1715	24.33	2561	2920	3203
17	Acid phosphate 480; muriate potash 260; nitrate soda 220; dried blood 25	44.12	2260	48.84	2338	21.64	2253	3096	3264
18	**Yard manure 16 tons**	**49.00**	**2460**	**42.88**	**2022**	**21.65**	**2345**	**3890**	**4071**
20	**Yard manure 8 tons**	**43.71**	**2178**	**37.81**	**1673**	**17.72**	**1878**	**2972**	**3513**
21	Same as plot 17 but nitrogen in oil meal	46.46	2255	47.57	2188	23.06	2398	2889	3125

TABLE XXII.

NOTE: The crop yields from each of ten plots receiving varying amounts of fertilizers are here compared with the average yield from ten plots receiving no fertilizers. All plots, both fertilized and unfertilized, are in a 5-course rotation of corn, oats, wheat, clover and timothy, and clover and timothy. From the complete experiment records of the Ohio Experiment Station the six plots in this rotation have been selected showing the largest net gain from the use of commercial fertilizers, (plots No. 2, 8, 11, 14, 17 and 21); the two plots showing the largest net loss from the use of fertilizers, (plots 5 and 9); and the two plots which were fertilized with barnyard manure only (plot No. 18 received 16 tons barnyard manure every 5 years, and plot No. 20 received 8 tons every 5 years). The cost of the commercial fertilizers, value of crop increase secured from their use, and the net gain or loss arising from the use of fertilizers are shown in Table XXIII. This table (No. XXII) is of value in making comparisons of yields of staple field crops in a 5-course rotation without manure or commercial fertilizers, with yields from the same crops in a similar rotation receiving applications of barnyard manure and commercial fertilizers.

TABLE XXIII.

NOTE: The figures shown in this table are based on the crop yields shown in Table XXII. Crop increases in comparison with unfertilized plots are computed by the methods described in the note accompanying Table XXI.

This table does not show a record of all plots in the 5-year rotation experiment at the Ohio Agricultural Experiment Station, but only the six plots showing the largest net gain from the use of fertilizers; the two plots showing the largest net loss from the use of fertilizers; and two plots that received applications of barnyard manure only.

The fertilizing materials are valued at a fraction over $16.00 per ton for acid phosphate; 2½ cents per pound for muriate of potash and 3 cents per pound for nitrate of soda.

Market value is the nearest practical approach to a common denominator for the various kinds of produce grown in this rotation. Therefore, the crop increases resulting from the use of various fertilizing materials are given a market value, corn being rated at 40 cents per bu., oats at 30 cents, wheat at 80 cents, hay at $8.00 per ton, corn stover at $3.00 per ton, and straw at $2.00 per ton. These values are below present prices for grain, but not far from the average values during the period of the test.

Table XXIII. Five-Year Rotation of Corn, Oats, Wheat, Clover and Timothy, and Clover and Timothy. Total Fertilizing Materials and Their Cost. Total and Net Value of Increase Produced for 5-Year Periods, and for 19 Years, 1894-1912. Calculations Made for One Rotation of 5 Years.

(Table V, Circular 131, Ohio Agricultural Experiment Station.)

Plot No.	Fertilizing Materials in Pounds per Acre for Each Rotation	Cost of Fertilizers for each Rotation	Average Value of Total Increase per Acre for Each Rotation				Net Gain or Loss from Fertilizers for Each Rotation			
			First 5 Years	Second 5 Years	Third 5 Years	19 Year Average Total	First 5 Years	Second 5 Years	Third 5 Years	19 Year Average Total
		Dollars	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
2	Acid phosphate 320	2.60	8.50	17.37	24.32	16.71	5.90	14.77	21.72	14.11
5	Nitrate soda 440; dried blood 50	14.40	4.70	10.47	9.30	8.50	— 9.70	— 4.00	— 5.37	— 5.90
8	Acid phosphate 320; muriate potash 260	9.10	14.40	24.37	33.51	24.81	5.30	15.27	24.41	15.71
9	Muriate potash 260; nitrate soda 440; dried blood 50	20.90	5.85	11.35	13.23	11.24	—15.05	— 9.55	— 6.67	— 9.66
11	Acid phosphate 320; muriate potash 260; nitrate soda 440; dried blood 50	23.50	26.39	42.43	49.96	39.31	2.90	18.93	26.46	15.81
14	Acid phosphate 240; muriate potash 180; nitrate soda 280; dried blood 50	16.05	21.37	32.91	37.33	30.35	5.32	15.86	21.28	14.30
17	Acid phosphate 480; muriate potash 260; nitrate soda 220; dried blood 25	17.60	15.74	36.61	46.28	34.95	— 1.86	19.01	28.68	17.35
18	**Yard manure 16 tons**	......	**19.82**	**34.24**	**55.94**	**39.84**	(See note accompanying).			
20	**Yard manure 8 tons**	......	**13.02**	**21.28**	**35.36**	**24.54**	(See note accompanying).			
21	Same as Plot 17 but nitrogen in oil meal	17.60	20.43	36.25	42.24	33.36	2.83	18.65	24.64	15.76

This table shows that the effectiveness of the fertilizers and manure has increased with each successive rotation period, the greatest relative increase being shown by the manure. The use of nitrate of soda or muriate of potash, unaccompanied by some carrier of phosphorus, produced a loss in each rotation period and in the average for nineteen years. Nevertheless, both nitrogen and potassium are essential to the highest net profit as shown by comparing plot 2 receiving phosphorus only with plot 8 receiving potassium in addition, and with plot 11 receiving these with nitrogen.

The most interesting feature of this table is the increase produced through the use of yard manure in the rotation. Plot 18, receiving 16 tons of manure once in five years, leads all other plots in average increase over the unfertilized plots for nineteen years. Plot 20, also, receiving but eight tons of manure once in five years, produced a very substantial crop increase, as compared with the unfertilized plots, and an increase that compares favorably with many of the plots receiving expensive applications of commercial fertilizers.

The Ohio Experiment Station has not set a cost price on the manure used in this experiment and thus no net gain appears to compare with net gain or loss from the use of commercial fertilizers. In farm practice manure is a by-product of crop production and the feeding of live stock, and there is no cost attached to it other than the labor cost of hauling it out to the land. On the average American farm the cost of hauling and distributing eight tons of manure would not exceed $3.00, and $6.00 for 16 tons, and would probably average less. Using these costs, however, the net gain from the use of 16 tons of yard manure would be $33.84 per acre for each 5-year rotation cycle, and the net gain from the use of eight tons of yard manure would be $21.54 per acre for each 5-year rotation cycle, thus giving the manured plots the highest net gains of all plots in the experiment.

In actual farm practice the fertilizing of land with the amounts of commercial fertilizers used on plots 8, 11, 17 and 21 (the four fertilized plots having highest net gain) would lay a financial burden on the farm manager that in many cases would be difficult to meet. Such fertilizers would cost from $2.00 to $3.50 per acre annually, and, while the net gain might justify the investment, the practice would annually tie up a considerable portion of the farmer's capital and in many cases be entirely impractical.

It may easily be seen from this experiment that a judicious combination of yard manure and phosphorus in this rotation would produce large crop increases with a large net gain and with an investment in fertilizers so small as to be entirely practical for the average American farmer.

Table XXIV. Three-Course Rotation of Corn, Wheat and Clover. Yields from Unfertilized Plots Compared with Yields from Plots Fertilized with Complete Fertilizers, Stall Manure Alone, and Stall Manure in Combination with Raw Phosphate, Acid Phosphate and Kainit. 16 Years, 1897-1912.

(Table VIII, Circular 131, Ohio Agricultural Experiment Station.)

Plot No.	Fertilizing Materials in Tons and Pounds per Acre for Each Rotation Cycle	(*) Corn 15 Crops		(*) Wheat 15 Crops		(†) Lbs. Clover Hay per Acre 12 Crops
		Bus. Grain per Acre	Lbs. Stover per Acre	Bus. Grain per Acre	Lbs. Straw per Acre	
	Average yield of 8 plots unfertilized	**34.39**	**2169**	**10.63**	**1310**	**2697**
3	**Stall manure 8 tons; raw phosphate rock 320 lbs.**	**65.41**	**3680**	**25.39**	**2791**	**5021**
6	**Stall manure 8 tons; acid phosphate 320 lbs**	**66.05**	**3581**	**25.47**	**2837**	**5077**
9	Stall manure 8 tons; kainit 320 lbs	61.01	3548	21.85	2596	4490
16	**Stall manure only, 8 tons**	**59.49**	**3358**	**20.69**	**2368**	**4149**
18	Acid phos. 80 lbs; muriate of potash 80 lbs; nit. soda 160	46.20	2731	14.22	1701	3248
19	Acid phosphate 80 lbs; muriate of potash 10 lbs; tankage (7-30) 100 lbs	45.54	2549	14.49	1804	3382

(*) Excluding crop of 1909 which was so injured by grub worms that no comparisons are possible.

(†) During the first three seasons of this rotation the clover crop failed and soy beans were sown and plowed under.

Note: In this table six plots in the experiment have been selected to compare with the unfertilized plots. The complete experiment includes a comparison of yard and stable manure as well as the use of gypsum.

There are two features of this experiment that are worthy of special note, (1) the approximately equal increases secured by raw phosphate rock and acid phosphate in combination with manure, and (2) the increase of yield from manure and raw phosphate as compared with manure alone and manure in combination with potash in kainit.

It may be noted from Table XXV, that the 320 pounds of raw phosphate rock cost but 58% of the cost of acid phosphate, and from Table I, it may be noted that the 320 pounds of raw phosphate rock carries nearly twice as much phosphorus as the acid phosphate.

Table XXV. Three-Course Rotation of Corn, Wheat and Clover. Average Annual Increase per Acre of Fertilized Plots over Unfertilized Plots. Cost of Fertilizers per Acre per Rotation Cycle. Total and Net Value of Increases per Acre per Rotation. 16 Years, 1897-1912.

(Table IX, Circular 131, Ohio Agricultural Experiment Station.)

Plot No.	Fertilizing Materials in Tons and Pounds per Acre for Each Rotation Cycle	Average Annual Increase per Acre: Corn 15 Crops, Bushels Grain	Corn 15 Crops, Pounds Stover	Wheat 15 Crops, Bushels Grain	Wheat 15 Crops, Pounds Straw	Pounds Hay 12 Crops	Cost of Fertilizers per Acre per Rotation	Value of Increase: Total per Acre for One Rotation	Value of Increase: Net per Acre for One Rotation
							Dols.	*Dols.*	*Dols.*
3	**Stall manure 8 tons; Raw phosphate rock 320 lbs**	**31.67**	**1,514**	**14.42**	**1,462**	**2,423**	**1.40**	**37.63**	**36.23**
6	**Stall manure 8 tons; Acid phosphate 320 lbs**	**34.95**	**1,561**	**15.75**	**1,630**	**2,724**	**2.40**	**41.45**	**39.05**
9	Stall manure 8 tons; Kainit 320 lbs	28.49	1,519	12.16	1,373	2,022	2.70	32.87	30.17
16	Stall manure only 8 tons	23.88	1,091	10.32	1,085	1,520	.....	26.61	.....
18	Acid phosphate 80 lbs.; Muriate of potash 80 lbs.; Nitrate of soda 160 lbs	10.21	485	3.90	378	513	7.45	10.14	2.69
19	Acid phosphate 80 lbs.; Muriate of potash 10 lbs.; Tankage (7-30) 100 lbs	10.97	421	4.45	484	646	2.30	11.37	9.07

NOTE: The increased yields of fertilized plots over unfertilized plots, shown in this table, are computed from figures in Table XXIV, by methods outlined in note accompanying Table XXI.

In giving crop increases a cash value the average prices of 40 cts. per bushel for corn, 80 cents per bushel for wheat, $8.00 per ton for clover hay, $3.00 per ton for corn stover, and $2.00 per ton for straw, have been used.

The Ohio Experiment Station has reckoned no costs for the manure in this table and, therefore, no net value is shown for the plot receiving stall manure only. If we assume an arbitrary, approximate cost of $3.00 for distributing eight tons of manure, the net value of the increase on the plot receiving manure only is $23.61; manure and rock phosphate, $33.23; manure and acid phosphate, $36.05; and manure and kainit, $27.17.

It should be noted how much greater the net value of the crop increase is from a combination of manure and raw phosphate rock, or acid phosphate, than from "complete fertilizers."

Table XXVI. Average Annual Yields of Corn, Wheat, Oats and Clover Hay, and Average Gross and Net Crop Values per Acre from Continuous Cropping without Fertilizers, Rotation Cropping without Fertilizers, and Rotation Cropping with Fertilizers. For 16 to 19 Years at the Ohio Agricultural Experiment Station.

(From Circular 131, Ohio Agricultural Experiment Station.)

Crops, Methods of Cropping, Amounts of Fertilizing Materials	Bus. Grain per Acre	Lbs. Stover Straw or Hay per Acre	Gross Crop Value per Acre	Annual Fertilizer Cost per Acre	Net Crop Value per Acre
CORN					
			Dollars	*Dollars*	*Dollars*
Continuous—no fertilizer	**15.88**	**1,245**	**8.22**	....	**8.22**
5-year rotation—no fertilizer	**29.74**	**1,668**	**14.40**	....	**14.40**
3-year rotation—no fertilizer	**34.39**	**2,169**	**17.01**	....	**17.01**
5-year rotation with 16 tons manure every rotation cycle	49.00	2,460	23.29	1.20	22.09
5-year rotation with 8 tons manure every rotation cycle	43.71	2,178	20.75	.60	20.15
3-year rotation with 8 tons manure every rotation cycle	59.49	3,358	28.83	1.00	27.73
5-year rotation with 320 lbs. acid phosphate every rotation cycle	37.83	1,871	17.94	.52	17.42
5-year rotation with 480 lbs. acid phosphate; 260 lbs. muriate potash; 220 lbs. nitrate soda; and 25 lbs. dried blood every rotation cycle	44.12	2,260	21.04	3.52	17.52
3-year rotation with 8 tons manure and 320 lbs. raw phosphate every rotation cycle	**65.41**	**3,680**	**31.68**	**1.47**	**30.21**
3-year rotation with 8 tons manure and 320 lbs. acid phosphate every rotation cycle	66.05	3,581	31.79	1.80	29.99
WHEAT					
Continuous—no fertilizer	**7.52**	**938**	**6.95**	.	**6.95**
5-year rotation—no fertilizer	**10.21**	**1,045**	**9.21**	.	**9.21**
3-year rotation—no fertilizer	**10.63**	**1,310**	**9.81**	..	**9.81**
5-year rotation with 16 tons manure every rotation cycle	21.65	2,345	19.66	1.20	18.46
5-year rotation with 8 tons manure every rotation cycle	17.72	1,878	16.05	.60	15.45
3-year rotation with 8 tons manure every rotation cycle	20.69	2,368	18.92	1.00	17.92
5-year rotation with 320 lbs. acid phosphate every rotation	18.12	732	15.23	.52	14.70
5-year rotation with 480 lbs. acid phosphate; 260 lbs. muriate potash; 220 lbs. nitrate soda; 25 lbs. dried blood every rotation cycle	21.64	2,253	19.56	3.52	16.04
3-year rotation with 8 tons manure and 320 lbs. raw phosphate every rotation cycle	**25.39**	**2,791**	**23.10**	**1.47**	**21.63**
3-year rotation with 8 tons manure and 320 lbs. acid phosphate every rotation cycle	25.47	2,837	23.21	1.80	21.41

OATS

Continuous—no fertilizer	**22.92**	**921**	**7.80**	....	**7.80**
5-year rotation—no fertilizer	**31.00**	**1,300**	**10.60**	....	**10.60**
5-year rotation with 16 tons manure every rotation cycle	**42.88**	**2,022**	**14.88**	**1.20**	**13.68**
5-year rotation with 8 tons manure every rotation cylce	37.81	1,673	13.02	.60	12.42
5-year rotation with 320 lbs. acid phosphate every rotation cycle	40.73	1,683	13.90	.52	13.38
5-year rotation with 480 lbs. acid phosphate; 260 lbs. muriate potash; 220 lbs. nitrate soda; 25 lbs. dried blood every rotation cycle	48.84	2,338	16.99	3.52	13.47

CLOVER

(In the 5-year rotation the hay yields are averaged for 4th and 5th years.)

5-year rotation—no fertilizer	....	**2,267**	**9.07**	...	**9.07**
3-year rotation—no fertilizer	....	**2,697**	**10.79**	.....	**10.79**
5-year rotation with 16 tons manure every rotation cycle	......	3,980	15 92	1.20	14.72
5-year rotation with 8 tons manure every rotation cycle	.....	3,242	12.97	.60	12.37
3-year rotation with 8 tons manure every rotation cycle	......	4,149	16.60	1.00	15.60
5-year rotation with 320 lbs. acid phosphate every rotation cycle	.....	2,816	11 26	.52	10.74
5-year rotation with 480 lbs. acid phosphate; 260 lbs. muriate potash; 220 lbs. nitrate soda; 25 lbs. dried blood every rotation cycle	......	3,180	12 72	3 52	9.20
3-year rotation with 8 tons manure and 320 lbs. raw phosphate every rotation cycle	......	**5,021**	**20.08**	**1 47**	**18.61**
3-year rotation with 8 tons manure and 320 lbs. acid phosphate every rotation cycle	......	5,077	20.31	1 80	**18.51**

Note: In this table the most important features of the rotation and fertilizer experiments at the Ohio Agricultural Experiment Station have been summarized in such a manner as to make comparisons easy between continuous cropping, rotation cropping without fertilizers, and rotation cropping with fertilizers.

The yields here shown are the actual average yields. They are not absolutely comparable as here presented, because some averages are for 12 years, others for 15, 16 and 19 years; and also because the experiments in continuous cropping, 3-year rotation and 5-year rotation cropping, were conducted on different fields on the Ohio Experiment Farm, and variations in soil conditions might, therefore, affect the yields. These yields, however, were all secured on the same farm during an approximately similar period of time, and, if the comparisons here made are not absolutely scientific, they are at least very useful in indicating general conditions and tendencies arising from con-

tinuous cropping, rotation cropping without fertilizers, and rotation cropping with fertilizers.

In order to compare the results of these various systems of cropping in common terms, the crop products have been converted into cash values with the following prices that have been used by the Ohio Agricultural Experiment Station in its other crop computations: corn, 40 cents per bu.; wheat, 80 cents per bu.; oats, 30 cents per bu.; corn stover, $3.00 per ton; straw, $2.00 per ton; and clover and timothy hay, $8.00 per ton.

The annual fertilizer cost per acre has been computed by dividing the total fertilizer cost for each rotation by the number of years in the rotation, thus giving the average, annual cost that should be charged to any particular crop in the rotation. The cost of the farm manure has been estimated by the author at $3.00 for each eight tons, this cost representing the approximate amount of man and horse labor necessary to distribute this amount of manure, it being assumed that manure is a by-product of crop growing and live stock feeding that costs nothing for fertilizer except the cost of hauling and distributing. The commercial fertilizers used in these experiments are valued as follows: raw phosphate rock, $8.75 per ton; acid phosphate, $15.00 per ton; muriate of potash, $50.00 per ton; and nitrate of soda, $60.00 per ton.

The net crop value per acre, as shown in this table, is merely the net value after subtracting fertilizer cost from the gross crop value. This gives an excellent basis for comparisons of the various cropping systems and fertilizers.

The reader may note from this table (1) the increase of crop value due to rotation alone, (2) the increase of crop value in similar rotations due to the use of farm manures, and (3) the maximum increase in crop value produced by a combination of rotation, farm manures, and a small amount of phosphorus.

While there are certain soil areas in the United States to which the results of these experiments are not altogether applicable at the present time, the methods of soil management shown by these experiments to be the most profitable are applicable to the greater part of the improved farm lands of the United States. As American agriculture ages the greater will become the area of farm land to which the truths of these experiments will be applicable.

CHAPTER V

THIRTY YEARS OF CROP ROTATION — ILLINOIS

"Near the end of thirty years an average yield of 96 bushels of corn per acre on one field, and an average yield of 27 bushels of corn per acre on another field, must be accepted as the results of different systems of farming on land that was similar and uniform in the beginning. * * *

* * * The 96 bushels is the average yield per acre for the years 1905, 1906 and 1907 in one system of farming; and the 27 bushels is the average yield for the same years in another system of farming on land originally the same. Between these extremes other results have been obtained from several other systems of farming. * * *

* * * In the following table are given three year averages of the yields of corn secured in recent years, including 1907, which is the twenty-ninth year of the oldest experiments and the thirteenth year of a newer and more extensive series of experiments with crop rotations and soil treatment with special reference to two markedly different systems of farming, of which one is termed "grain farming" and the other "live stock farming."

Table XXVII. Corn Yields from the University of Illinois Experiment Field at Urbana. Typical Corn Belt Prairie Soil. Three Year Averages. Bushels per Acre.

(Table I, Bulletin 125, Illinois Agricultural Experiment Station.)

Crop Years	Crop System	13 Year Exp'ts.	29 Year Exp'ts.
1905-6-7	Corn every year......................	35 bu.	27 bu.
1903-5-7	Corn and oats rotation...............	62 bu.	46 bu.
1901-4-7	Corn, oats, and clover rotation	66 bu.	58 bu.

Average Yield Three Corn Crops, 1905, 1906, 1907, in Corn, Oats, and Clover Rotation. 13 Year Experiments.

Crop Years	Special Soil Treatment	(*) Grain Farming with Legumes	(†) Live-stock Farming with Manure
1905-6-7	None............................	69 bu.	81 bu.
1905-6-7	Lime; 1,000 lbs. per acre applied in 1902	72 bu.	85 bu.
1905-6-7	Lime; 1,000 lbs. per acre applied in 1902; phosphorus, 200 lbs. steamed bone meal applied annually...............	90 bu.	93 bu.
1905-6-7	Lime; 1,000 lbs. per acre applied in 1902; phosphorus, 200 lbs. steamed bone meal annually; potash, 100 lbs. sulphate of potash annually............	94 bu.	96 bu.

(*) Legume catch crops and crop residues plowed under.
(†) Manure applied in proportion to previous crop yields.
The cost of limestone delivered is about \$2.00 per ton; steamed bone meal \$25.00 per ton; and sulphate of potash \$50.00 per ton.

From Bul. 123, Illinois Agr. Expt. Station.

A plot of corn on the common prairie loam of Marion county, Illinois. Corn grown in a rotation of wheat, clover, corn and cowpeas. All crop products removed from the land. No fertilizers. Average yield four years: 38.3 bushels per acre.

As an average of the last three years where corn has been grown every year, the yield has been twenty-seven bushels per acre in the 29-year experiments, and thirty-five bushels per acre in the 13-year experiments. The lesson of these experiments is that twelve years of cropping, when corn followed corn, reduces the yield from more than seventy bushels per acre to thirty-five bushels per acre, after which the decrease is much less rapid, amounting to only eight bushels per acre reduction during the next sixteen years. Undoubtedly the rapid reduction during the first twelve years of continuous corn growing is due in large part to the destruction of the more active decaying organic matter, resulting ultimately in insufficient liberation of plant

From Bul. 123, Illinois Agr. Expt. Station.

A plot of corn on the common prairie loam of Marion county, Illinois. Corn grown in a rotation of wheat, clover, corn and cowpeas. Cowpeas plowed under for green manure. Soil amended with lime, phosphorus and potassium fertilizers. Average yield four years: 61.3 bushels per acre.

food within the feeding range of the corn roots. In addition to this, the development of corn insects in soil on which their favorite crop is grown every year is sometimes an important fact in reducing the yield.

Where corn is followed by oats in a two-year rotation, the average yield of the last three crops of corn is forty-six bushels per acre in the 29-year experiments, whereas, in the 13-year experiments, the average yield for the same three years is sixty-two bushels of corn per acre. In this case the destruction of humus is less rapid, and the development of corn insects is discouraged by changing to oats every other year, so that the decrease in yield is less marked during the early years, although the reduction continues persistently with passing years. During the first eleven years the yield decreased from more than seventy bushels to sixty-two bushels per acre, and during the next sixteen years a further reduction of sixteen bushels has occurred.

With the three-year rotation, corn is grown for one year, followed by oats with clover seeding the second year, and clover alone the third year. During the first ten years under this system the yield of corn has decreased from more than seventy bushels to sixty-six bushels per acre, and during the next sixteen years the yield has further decreased to fifty-eight bushels per acre. * * * In this system the most marked reduction in crop yields has not yet appeared, although it must be expected in the future, because the clover crop is already beginning to fail on the oldest field even in seasons when clover succeeds well on newer land under the same crop rotation. When clover fails, we substitute cowpeas for that year on that field, which thus provides a legume crop, and preserves the three-year rotation.

Grain Farming. * * * This system, when fully under way, provides that the corn shall be husked and the stalks disked down in preparation for the seeding of oats and clover the second year. In harvesting the oats as much straw as possible is left in the stubble, which may be mowed later in the summer to prevent the seeding of the clover or weeds. In the spring of the third year the clover is mowed once or twice before the usual haying time and left on the ground.

The seed crop, if successful, is harvested with a hay buncher attached to the mower, or in any other way to avoid raking, and, after threshing, the clover straw is returned to the land, all of this accumulated organic matter to be plowed under for the following corn crop which begins the next rotation. In addition to this, catch crops of annual legumes, such as cowpeas, may be seeded in the corn at the time of the last cultivation and disked in the next spring with the corn stalks. If biennial or perennial legumes are used as catch crops, the corn—corn ground may be spring plowed for oats.

The corn yields reported for this system in Table I. (p. 376) were secured when the system was not fully under way, the legume catch crops being the only organic matter returned to the soil, aside from the residues necessarily left from the oats—clover rotation.

* * * With no special soil treatment aside from the use of legume catch crops, the yield of corn for 1905, 1906 and 1907 in this system averaged sixty-nine bushels per acre; with addition of lime, seventy-two bushels per acre; with lime and phosphorus, ninety bushels per acre; and with lime, phosphorus and potash, ninety-four bushels per acre.

Live Stock Farming. * * * The plan of this system is to remove all crops from the land as usually harvested, including the corn and stover, oats and straw, and both first and second crops of clover. The amounts of manure applied to the different plots are determined by the crop yields secured during the previous rotation. While the system of cropping followed during the past thirteen years on these plots, and on those previously described under "grain farming," has been approximately equivalent to a three year rotation of corn, oats and clover, the applications of manure have been made only for the years 1905, 1906 and 1907. If the average yields are decreasing on plots that receive only the amounts of manure that can be produced in practice from the crops grown, then the applications of manure must also be reduced on such land; whereas, if the crop yields are increasing where both manure and phosphorus are applied, then the applications of manure for such plots may be increased in direct proportion.

Where manure alone has been used in this rotation the corn has averaged eighty-one bushels per acre for the last three years; with lime added, the average is eighty-five bushels per acre; with lime and phosphorus, the manured land has averaged ninety-three bushels of corn; and with lime, phosphorus and potash, the manured land has averaged ninety-six bushels per acre.

While potassium has usually made some increase in crop yields on these fields, it has not nearly paid its cost. The most profitable yields are the ninety bushel average in the grain farming, or the ninety-three bushel average in the live stock system. * * *

CHAPTER VI

THE RESULTS OF SCIENTIFIC SOIL TREATMENT ON AN ILLINOIS FARM.

(Excerpts from an Address by Frank I. Mann before the Illinois State Farmers' Institute, February 21st, 1911.)

It has been a great pleasure to me to be able to apply some of these scientific principles of permanent agriculture to the practical operations of farming for several years. The farm involved consists of about 500 acres of brown silt loam of the early Wisconsin glaciation, and is the so-called level black prairie land of the corn belt. It has been reasonably well drained, but the drainage outlet systems have not always been adequate for good drainage. The sub-divisions are mostly eighty acre fields. A four year rotation of corn, corn, oats, and clover has been conducted on most of the fields for about thirty years. Some small fields have rotated blue grass pasture with grain crops.

Under the permanent scheme phosphorus is the only element of plant food that, as yet, must be purchased to be added. To supply phosphorus, it was bought in raw rock phosphate, which was applied at the rate of 1,000 pounds per acre, once in four years, the application being made to the clover field in the fall before it was plowed for corn the following year. At this rate, the cost was approximately four dollars for each treatment, or an annual cost of one dollar per acre. Check strips three rods wide were left in each field without treatment with phosphate, but in every other respect they have been managed identically the same. These check strips were left in order to get a measure on the value of the treatment.

The following figures are the average yields per acre for five years, from comparative data taken from large fields. It should be remembered that the rotation including clover has been run so long that the clover alone (on the check

strips) is losing to some extent its efficiency for increasing yields.

The data given as yields on a two year rotation of corn and oats are taken from nearby fields, and are only approximate, though they compare favorably with general averages.

Table XXVIII. Crop Yields on an Illinois Farm. 5-Year Averages. Comparison between 2-Year Rotation of Corn and Oats; 4-Year Rotation of Corn, Corn, Oats, and Clover; and Same 4-Year Rotation with Addition of 1,000 Pounds Rock Phosphate Once in Four Years.

(Page 7, Circular 149, Illinois Agricultural Experiment Station.)

Two-year Rotation Corn and Oats	Four-year Rotation Corn, Corn, Oats, Clover	Same Four-year Rotation 1,000 lbs. Rock Phosphate once in 4 years
Corn 34 bu.	54 bu.	70 bu.
Oats 32 bu.	47 bu.	70 bu.
Clover	1½ tons	2½ tons

One important fact not shown in these figures is that the effect of this treatment is cumulative, as the difference in yields has a strong tendency to increase year after year.

Another important fact not shown fully is the benefit of the treatment in getting a stand of clover on certain parts of the fields. Some portions of the check strips show but little, if any, clover the second year after seeding, while on the comparable ground across the treated line there is a good stand. * * *

* * * Wishing to know if a maximum application of phosphate would be profitable, that is, an application large enough to bring the total phosphorus content up to the standard of 2,000 pounds per acre, average portions of the main fields were selected, to which an application of four tons of phosphate per acre was made. Also, some smaller fields have been given this full treatment, except for the check strip. The differences in yields for the past year (1910) indicate a good per cent of profit on the investment for this heavy treatment, as shown by the following figures:

Table XXIX. Crop Yields on an Illinois Farm, 1910. Comparisons between 2-Year Rotation of Corn and Oats; 4-Year Rotation of Corn, Corn, Oats, and Clover; same 4-Year Rotation with 1,000 Pounds Rock Phosphate per Acre Every 4 Years; and same 4-Year Rotation with 8,000 Pounds Rock Phosphate per Acre Every 4 Years.

(Page 10, Circular 149, Illinois Agricultural Experiment Station.)

Two-year Rotation Corn and Oats	Four-year Rotation Corn, Corn, Oats, Clover. 24 Years	Same Four-year Rotation with 1,000 lbs. Rock Phosphate once in 4 years	Same Four-year Rotation with 8,000 lbs. Rock Phosphate once in 4 years
Corn 25 bu.	67 bu.	84 bu.	92 bu.
Oats 31 bu.	55 bu.	78 bu.	89 bu.

Another advantage of the treatment is its effect on the maturity and quality of the crops. In view of the widespread and annually increasing complaint from the commercial interests of the poor quality of grain, this problem of maturity is an important one. There is a difference between mature grain and grain that merely stops growth at the proper season and then dries out. Maturity is a completion of the process of growth, and not merely a cessation of growth, and full development can not take place unless there is sufficient plant food. Grain will be light and chaffy whenever the crop is insufficiently supplied with the plant food necessary to full seed development. Some comparisons have been made between treated and untreated parts of fields as to maturity of the crops. In the case of corn, maturity has varied from 35% to 84% respectively, for the untreated and treated. No doubt some of this difficulty can be remedied by growing earlier maturing varieties, but with these the fact of immaturity still remains to some extent, for even the early varieties of pop corn with their small ears are likely to contain many immature ears. Plants will not properly mature when insufficiently fed any more than will animals, when not properly nourished. * * *

PART V

REVIEW OF SOIL PRODUCTIVITY

CHAPTER I

LESSONS FROM OTHER NATIONS

It is well known that the yields of such staple field crops as wheat, barley, oats, and potatoes average higher in England, Germany, France, Denmark, Holland, Sweden, Norway, Austria-Hungary, and Italy, than in the United States of America. Furthermore, these yields are secured on soil areas that were under cultivation for several centuries prior to the time when agriculture was first practiced in North America. The soil areas of the United States have all the advantages of newness and natural fertility, and yet yields are commonly less than on the old soil areas of Europe. What explanation can be given for this condition of American agriculture?

If a comparison be made between methods of agriculture in Europe and in the United States, it will be found that in both regions the use of good seed and improved varieties has become almost universally recognized as an essential factor of crop production, and that so far as this factor of crop production is concerned, conditions are about the same in both regions. A comparison of tillage implements will show that ordinarily the American farmer is provided with more efficient plows and tillage implements than the European farmer. Oftentimes, under the extensive systems of farming that prevail in parts of the United States, the

work of soil tillage is inferior to that on European soils where the necessity for deep and thorough tillage is well recognized, but, generally speaking, the tillage of American soil is as well done as the tillage of European soil. There is not sufficient difference here to account for the differences in crop yields. But, when we come to make comparisons of farming systems, crop rotations, the conserving and handling of farm manures, and the judicious use of commercial fertilizers, we find that the European farmer is in advance of the average American farmer. Herein are the reasons for the higher average crop yields of Europe.

In the first place, there is a larger proportionate amount of intensive farming in Europe than in the United States. Farms and fields are smaller and the soil is more carefully tended than the soil areas of many of our extensive American farms. Along with the more intensive system of farming there is a more universal use of crop rotation, including legume crops and forage crops fed to live stock. In the matter of conserving and handling farm manures the average European farmer is ahead of the American farmer. Absorbents are used to retain all urine waste, and great care is used in the composting or direct hauling of manure to prevent losses from fermentation and leaching.

In the matter of plant food deficiencies in soil, arising from natural distribution of the elements of plant food or from a long continued farming system that impoverished the land, the European farmer has been making a judicious use of commercial fertilizers for many decades to amend the plant food deficiencies of his soil. The merchant vessels of Great Britain, Germany, France and Norway, have been carrying a constant stream of soil fertilizers to European soils for the past sixty years. Great deposits of guano (the dung of sea fowl deposited in sheltered nooks along certain

coasts), rich in phosphorus, were transported from South America to Europe and used to build up European soils, and, when the guano deposits were mainly exhausted, Europe began to import phosphate rock from the United States.* European farmers, for the past fifty or sixty years, have invested huge sums of money in commercial fertilizers to amend the plant food deficiencies of soils that had been unscientifically tilled by previous generations.

In comparing the agriculture of the United States of America with that of Europe, it should also be remembered that Europe, as a whole, has been an importer of foodstuffs for the past thirty to forty years while the United States of America has been an exporter of the products of the soil. Europe has a comparatively dense population, mainly engaged in manufacturing, and for many years past has been a heavy importer of food products from all over the world. Wheat is imported from Russia, the United States, Canada, North Africa, and Argentine, and live stock products from Australia, Canada, Argentine, and the United States. Furthermore, the European dairyman and live stock feeder utilize large amounts of mill feed from the United States and Canada and, large amounts of soy bean cake from Manchuria that is rich in nitrogen and phosphorus. In consideration of all these economic conditions

(*) During the five-year period 1908-1912 the total marketed production of phosphate rock from the mines of the United States was 15,014,721 short tons, of which 5,650,607 tons, or 37.6% was exported to foreign countries. An analysis of the statistics on phosphate rock exports 1908-1912 shows that 35.8% of our total marketed production for this period was exported to European countries. Germany was the heaviest buyer during this period, taking 10.6% of our total product; France bought 4.5% of our total product; Great Britain, 4.3%; Italy and the Netherlands, each about 4%; and the balance of the exports was scattered among various countries of Europe, North America, Asia and South America. In 1912 Japan purchased 3.2% of the 1912 marketed product, or approximately the same amount as was purchased by Italy or the Netherlands.

which surround the agriculture of Europe, it is easy to see why the European farmer maintains the fertility of his soil better than the average American farmer who has been a citizen of a nation that exports the raw products of the soil. European agriculture, on the whole, is very similar to the agriculture pursued on occasional American farms that keep more live stock than the farm can support and purchase additional grains and mill feeds produced by other farmers to meet the deficiency. This system produces large amounts of manure containing some plant food from another person's farm, and there is no difficulty about maintaining soil productivity under such conditions.

Many of the European cities recover considerable fertilizer material from city garbage and sewage that is made use of by near-by truck farmers, while in the United States no such fertilizer values are recovered and the drainage streams carry off countless tons of valuable plant food.

Turning from Europe to Asia, we may see object lessons in soil fertility problems on soils that have been cultivated since the dawn of history. The author has seen soil areas in Central China that have been cultivated continuously since a period that was at least 1,000 B. C. and that are still producing profitable crops, and also soils in Korea and Japan that are known to have been under cultivation for a thousand years or more. Very few of these old soils in Asia have ever received any applications of commercial fertilizers, nor has crop rotation, the use of legume green manure crops, or the feeding of farm crops to live stock been employed to maintain the productivity of the soil. The tillage methods also are not usually as good as those practiced on the best American farms using the best types of modern tillage implements. The whole secret of the age of Chinese, Japanese and Korean agriculture lies in the wonderfully painstaking precautions

these people take to recover all forms of human and animal excrement and to return such matter to the soil with a minimum of loss from fermentation and leaching. The old men and the boys of China frequent the highways to gather up all droppings from beasts of burden. Human excrement in both country and city is very carefully conserved and is an article of commerce in the cities where population is dense. The greater part of all animal and human excrement in China and Japan is recovered and returned to the soil. After it is gathered, it is stored in great vessels or in pits lined with impervious clay, and applied to the soil just prior to seeding or during the early stages of crop growth. Thus the percentage of loss from fermentation and leaching is very small.

There are many farming communities in North China, also, where it is a common practice to dig great pits into the soil and to take out large amounts of subsoil annually for use as fertilizer. The soil taken from these pits is mixed in compost heaps with dung, urine, and garbage, and shoveled over, mixed up, and aerated several times before it is hauled on the land.

By these careful, painstaking methods in the conserving of animal and human excrements, many soil areas in China and Japan have been kept productive for very long periods of time. Small plots of land, carefully tilled, with an almost perfect check on subtractions of plant food from the original supplies of the soil, are the reasons for the maintenance of productivity on many soil areas of the Orient.

But all the soil areas of the Orient are by no means being cultivated under a permanent scheme of agriculture. There is abandoned land in China as well as large areas of agricultural land where yields are now very low and where the fertility of the soil is rapidily diminishing. This is particularly

true of the naturally fertile agricultural lands in Manchuria and North China. This region exports large quantities of agricultural produce to South China, Japan, and Europe. The population is not so dense as in South China, the farms and fields are larger, and, as a considerable portion of the crops is exported, there is a constant drain on the soil's store of plant food that is not offset by the recovery of an equal amount of plant food in animal and human excrement. In addition to this, the tillage is very shallow, there is no use of green manure crops, pasture crops or meadow crops, and all crops are inter-tilled. Humus is rapidly exhausted from these soils by these practices as well as the common practice of digging out crop stubble for fuel. The farmers of this region conserve such animal and human excrement as is available; but it is insufficient to counterbalance the plant food taken out by crops and exported from the country.

The author has seen many agricultural districts in Manchuria that have been under cultivation only seventy-five to one hundred years, where crop yields were at a very low level, and where, within the memory of men now living, the yields were double or treble the present-day yields. Many of these impoverished lands are merely in poor physical condition and not absolutely impoverished as regards total amounts of plant food. It is plain, nevertheless, that, if these soils were put into good physical condition again, humus added to the soil to release new supplies of available plant food, and a new lease of productivity so given, the ultimate unproductivity of the land would be deferred only a generation or so longer, providing the present methods of agriculture were to continue.

The soil conditions that prevail in the exporting regions of North China and Manchuria are quite similar to the

conditions that now exist in the North Central states of the United States, and are an object lesson worthy of consideration by the American farmer of the Middle West. In those regions of China where the subtractions of plant food from the soil by crops are being offset by the additions of plant food in animal and human excrement, agriculture is practically permanent, and yields are as high now as in generations past. In regions like Manchuria, where crops are exported and the subtractions of plant food from the soil by crops permitted to exceed the additions made through fertilizing materials, soil productivity has diminished in seventy-five to one hundred years to a very low level, and caused the abandonment of some land that has been so cropped for two hundred to three hundred years.

Similarly, in many parts of the United States, the systems of farming that have been in use for the past generation have tended to greatly reduce the natural supplies of plant food in the soil, and a further continuance of such methods of agriculture will ultimately cause very low yields and abandoned soil areas, as similar agricultural practices have done on some of the older soil areas of the Orient. The lesson we can best note from the older agriculture of the Orient is the value of keeping a balance between the outgo and the income of plant food in the soil. We may not yet be able or desirous to maintain this balance by the same methods that are employed by the Oriental farmers; but we have the facilities for so doing, if we will but use them.

PROBLEMS AND PRACTICUMS

(1) What is the average yield per acre of wheat, oats, and barley in England, Germany, France, and the United States of America?

(2) What was the total production of wheat in the United States in the years 1870, 1880, 1890, 1900 and 1910? What per cent of the crop was exported to foreign countries at these dates?

CHAPTER II

DEPLETION AND MAINTENANCE OF AMERICAN SOILS

American agriculture is very new as compared with the agriculture of Europe and Asia. We have a very few soil areas along the Atlantic Seaboard that have been tilled from two hundred to three hundred years. Other areas of some size in the South Central states and the southern part of the North Central states have been under cultivation from seventy-five to one hundred years; but the largest part of the present agricultural soil areas of the United States has been put under cultivation only within the last fifty or seventy-five years. Compared with the agriculture of Asia and Europe, ours is so new as to be infantile. With the best part of a great continent at our disposal, we have been at work during our entire national existence in the task of subduing virgin land. The restless American spirit has been well adapted to this work, and, aided in the past fifty years by the modern methods and inventions for facilitating communication, the American people have accomplished marvelous results in the subduing of a wild continent and the creation of wealth from natural resources. One railway after another has been projected into the wild regions of North America and in its wake have come the settler, the breaking plow, the grain elevator, the export of foodstuffs to feed the world, the quick realization of fortunes from the virgin fertility of the soil, and, eventually, a decrease in available soil fertility and a problem in the maintenance of soil productivity for the succeeding generations to face.

In the latter part of the seventeenth century, Bishop Berkeley, the English philosopher-poet,. coined the famous epigram, "Westward the course of empire takes its way," and in the first part of the twentieth century, Dr. C. G. Hopkins, the American soil chemist, added to this epigram the words, "leaving impoverished lands behind." These few words added to Berkeley's famous epigram give a clever and accurate epitome of the history of agriculture in the United States of America. It has always been easier and more profitable in the United States to develop new land of virgin fertility than to go to the trouble and expense of maintaining productivity on the older soils. We still have a vast amount of virgin land to subdue and put under cultivation. There are millions of acres of desert land awaiting the irrigating ditch to create real wealth from their potential wealth; millions of acres of cut-over timber lands, especially in the North Central and South Central states, awaiting the stump puller and the brush plow to convert inert stores of plant food into grain, milk and meat; and there are millions of acres of swamp land awaiting the drainage ditch that will carry off the excess water that now prevents these lands from producing valuable crops. Pioneer agriculture is by no means at an end in the United States. Not yet have all the waste places been made productive and habitable. There are still vast stretches of wild land to occupy the attention of the restless pioneer, development spirit of the American people.*

Nevertheless, the most accessible, most fertile, and most

* In 1914 the United States Department of Agriculture estimated that of the 1,143,000,000 acres of arable land in the United States only 27% or 311,000,000 acres were actually in crop, leaving a balance of 832,000,000 acres of fair to good arable land still awaiting the breaking plow. It is further estimated that there are 361,000,000 acres of land available for pasture and tree crops, and 399,000,000 acres that are irreclaimable and worthless for agriculture.

easily subdued lands of the United States have already been put under cultivation. The increase in the acreage of farm land in the United States during the next generation will undoubtedly be much slower than in the past one. Wild lands will be subdued and the acreage of farm land will increase, but the increase will be comparatively slow as judged by the increase in acreage that took place from 1870 to 1910. The increase in our acreage of virgin farm land can no longer be made sufficiently rapid to keep pace with our increase in population and the decreasing yields on some of our older soil areas. Our best and most easily tilled soil areas are already developed, and the time has come for the American people to take stock of their agricultural resources, to give more attention to the permanency of their agriculture, and more consideration to intensive farming and higher yields per acre as a means for swelling the total agricultural wealth of the nation.

The prophets of depleted soil fertility have never been taken very seriously in the Middle Western and Western sections of the United States. So long as virgin fertility was abundantly available for crops, the virgin soil areas were regarded so rich as to be of inexhaustible fertility. Extravagant ideas, language, and methods have prevailed, as a matter of course, with every new soil area of any size that has ever been opened in the United States. It was not to be expected that men would or could consider the future conditions of soil fertility when crops were abundant and soil fertility apparently inexhaustible. The prophecies of depleted soil fertility fell on ears that did not hear. Men either disbelieved or did not care. Disbelief was not surprising when we consider the wonderful fertility of the virgin prairies of the United States and the comparisons that the Eastern bred farmer made with the soil areas of New England states

The point of view is an important factor in controlling the actions of men. The pioneer farmer of the Middle West who came from the stony hillsides of New England is not to be blamed for having developed the point of view that credited Western soil with inexhaustible fertility. It is characteristic of all men also to live in the present. If the present is a time of plenty and of bountiful crops, why bother about the future? The Irish witticism, "Why consider posterity, what did posterity ever do for us?" is the rule of business and of politics that commonly prevails and that often creates serious problems of finance, politics, or agriculture for posterity.

The history of agriculture in the great Red River Valley region of Minnesota and North Dakota is a very typical example of the American farmer's attitude toward the problems of soil fertility. When this region was being opened and put under cultivation in the years 1870 to 1890, it was described in business circles with the most extravagant of adjectives. It was enthusiastically called the "bread basket of the world," a region having "the richest soil in the world," "a valley more fertile than the valley of the Nile," and "a region having a soil of such perfect composition as to be of inexhaustible fertility." Farmers, bankers, real estate men, and railway men thoroughly believed these statements about the Red River Valley. The pioneer farmers in the Red River Valley dumped the manure that accumulated on their farms into the Red River. On farms not close to the river the manure would pile up around the horse barns in such quantity as to often interfere with getting in and out of the barn. When such a condition arose, the barn would be "jacked up," put on rollers, and changed to a new location, and the manure piles burned up. The prophets of depleted soil fertility were as voices in the wilderness in those days.

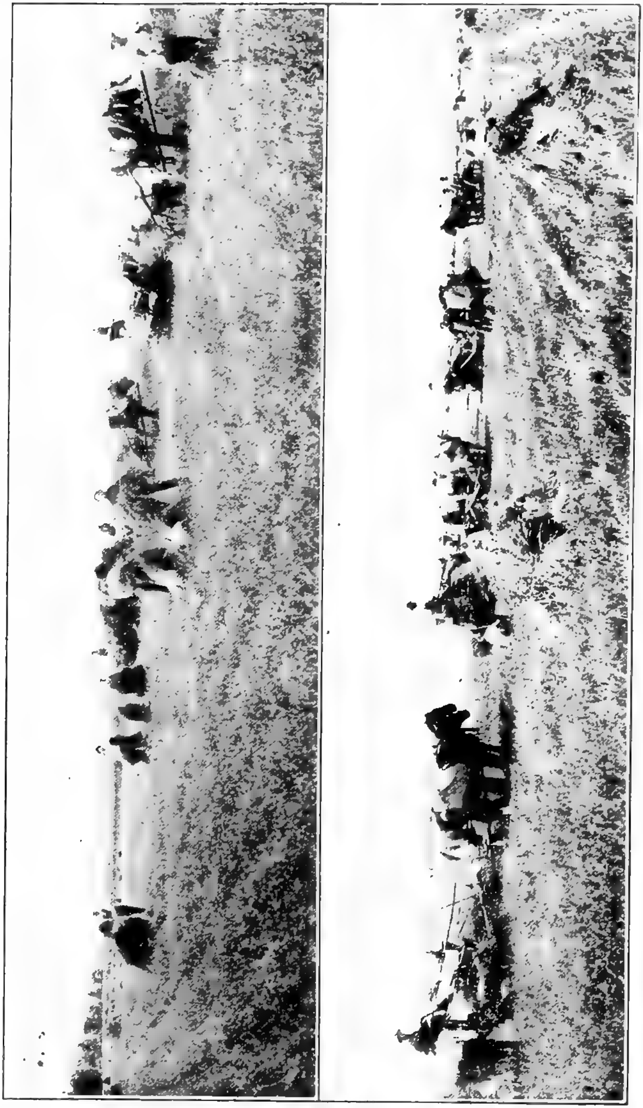


Photo by courtesy N. S. Davies, Red River Valley Development Association.

Harvest scene on one of the old bonanza wheat farms of the Red River Valley. Continuous, extensive grain growing, practiced for several decades after the virgin land was broken, resulted in low productivity for grain crops.

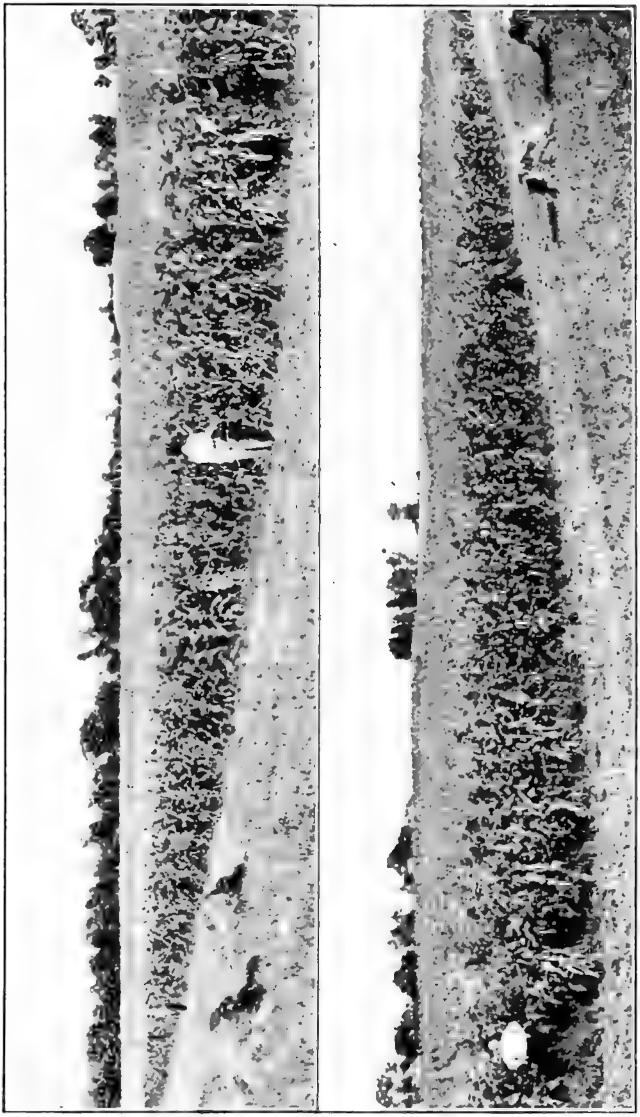


Photo by courtesy N. S. Davies, Red River Valley Development Association.

Continuous grain growing in the Red River Valley is giving way to cropping schemes that include acclimated varieties of corn, clover and small grains, and as a result the abundant reserve supplies of plant food in the soil are made available to crops.

Everybody believed that the soil of the Red River Valley was of inexhaustible fertility. Moreover, experience had shown that, if manure was spread on the virgin land, the excess of nitrogen so provided caused rank growing grain crops with weak straw that easily lodged, and a crop that inclined to too much straw and too little grain.

These ideas were the accepted theory for agricultural practice in the Red River Valley until about 1905. Practically every farmer was a wheat farmer, and the majority of farmers tilled their land on the theory of inexhaustible soil fertility, with no need for crop rotation, green manures, meadow and pasture crops, and animal manures. By 1905 the continuous growth of grain crops had exhausted much of the soil's supply of available plant food, decreased the amount of humus, created unfavorable physical soil conditions, and caused an accumulation of noxious weeds. As a result, farmers began to notice decreased yields and lower grades in their grain crops. In a period of time that varied from fifteen to thirty years on different farms the theory of inexhaustible soil fertility had received a hard jolt, and the progressive farmers of the Red River Valley began to listen more and more to the prophets of depleted soil fertility and began to practice more diversified farming, crop rotation with the inclusion of legume crops and cultivated crops, and to use some live stock to check the sale of plant food from the soil. Wheat and other small grains are still largely grown in the Red River Valley, but not to the entire exclusion of other crops.

The most profitable farms in the Red River Valley to-day are those that combine alfalfa or red clover and corn or potatoes in a rotation with the small grains, and on which a portion of the crops is fed to live stock and the manure returned to the land. The soil is still very rich in total amounts

of plant food. At the present time and for much time to come it needs a system of farming that will maintain the humus equilibrium and nitrogen, and provide conditions for a continuous liberation of plant food from the large reserve supplies in the soil. In some parts of the Valley there are whisperings of a need for phosphate fertilizers, and it is possible that in another generation or two there will be a real need for them to amend the phosphate deficiencies of some soils. Thus has time changed the point of view in regard to the productivity of the soils of the Red River Valley, and what is true of this soil area is characteristic of every soil area in the United States in varying degree and with slight differences depending on the original composition of the soil.

American agriculture has already exhausted and wasted large amounts of the nation's original assets of plant food in the soil. In many of the wheat growing regions the phosphorus content of the soil has been reduced to a point where comparatively low yields are now the rule and where the average grade of the grain is low. In many rich farming regions such as Iowa, Illinois, Southern Minnesota, Missouri and Eastern Nebraska, farmers complain that clover does not yield as well as fifteen to twenty years ago, and increasing difficulty is being experienced to secure profitable corn crops. In these instances, also, a deficient supply of available phosphorus in the soil is usually the cause of the farmer's difficulty in securing maximum yields of high grade products.

Comparatively young as American agriculture is, there are undoubtedly many large soil areas already needing amendment, particularly as regards phosphorus. We have reached a stage in the progress and development of our agriculture where, as a nation, we must give greater consideration to the problems of maintaining soil productivity

and less consideration to the problems of subduing virgin lands. As our best farm lands are already under plow, we can henceforth add more to our national food supply through increasing and maintaining the productivity of our developed soil areas than through the addition of more tillable land to our total farm land area. The subduing of virgin lands should receive due attention; but to maintain a high productivity on the farm lands already under cultivation is much more important.

The same methods cannot be applied to all soils to maintain a condition of high productivity. In many cases the soil is still abundantly fertile in total supplies of plant food; but the amounts of available plant food have been reduced to a point too low for profitable cropping. This is a soil condition that is commonly found in every part of the United States, even in some of the older regions that have been using commercial fertilizers for many years. This condition in the soil is brought about by continuous cropping to any class of crops, shallow plowing, non-use of any deep rooted crops, and the non-use of crop rotation, green manures and live stock manures to maintain nitrogen and humus in the soil. It is a soil condition affecting productivity, quickly and easily corrected by means of thorough tillage, green manure crops and a well planned rotation of crops.

When an analysis of the soil, however, reveals the fact that the total phosphorus or potassium supplies of the soil are below a minimum amount necessary to permit an annual liberation of available phosphorus or potassium in sufficient amounts for maximum crops (even when green manuring, crop rotation, and thorough tillage are practiced), there is but one practical and profitable method to follow to increase the productivity of the soil, and that is to amend the soil and correct its deficiencies with the commercial fertilizer

best adapted to the particular soil and its needs. The amendment of a soil to correct some prominent plant food deficiency is best accomplished when the commercial fertilizer is used in conjunction with green manures, animal manures, and a good system of crop rotation.

In planning systems of farming that will maintain the productivity of our older soil areas it should be remembered always that no amount of crop rotation and green manuring with all the crops of the farm fed out to live stock, and the manure returned to the land, can actually add any essential plant food to the soil except nitrogen. Such a system of agriculture, if inaugurated on a soil naturally rich in phosphorus and potassium, and prior to excessive exhaustion of these forms of plant food, will keep the soil in a state of high productivity for long periods of time, because very little phosphorus or potassium is sold away from the land and because good conditions are always provided for the liberation of plant food in the soil. But, if a phosphorus or potassium deficiency is known to exist no amount of green manuring and crop rotation will benefit the soil in this respect. The correction can be made only by means of the commercial fertilizer.

Agricultural experience all over the United States has clearly indicated that phosphorus is the element of plant food most likely to become deficient in our agricultural soils. For this reason we, as a nation, should more carefully safeguard our natural stores of phosphate rock against that day when many of our soils will be in great need of phosphorus amendment. We have already exported large quantities of phosphate rock from the deposits in the Southern states, but we have extensive phosphate deposits in the Public Domain of the Western states that should be carefully safeguarded for the future use of the American farmer.

To further safeguard the productivity of American soils and the future food supplies of the nation we should take a leaf from the history of Oriental agriculture that has kept soil productive for thirty to forty centuries by means of a crude system of checking the waste of plant food that takes place when the excrement of human bodies is allowed to go to waste. Our American cities are the greatest of all wasters of the fertility of our soils. They receive countless tons of plant food from the soil, actually consuming but a small fraction thereof and returning but a small fraction to the soil, the larger part being run off to the ocean in sewage. Our standards of living and methods of sanitation do not as easily permit of the saving of this waste of plant food as in case of a city in Southern China, and yet should our public leaders, our financiers, and our civic engineers turn their attention to it, the problem could be solved without great difficulty. Large municipal septic tanks and garbage incinerators to conserve the plant food in waste products of great city populations would be practical, profitable and comparatively easy to install. The saving of city waste is now practiced to some extent in European cities and it is bound to come in the large cities of the United States. We cannot afford to go on forever mining plant food from the soil, transporting it to our centers of population, and then running it off to the oceans.

The conservation of plant food in the soil is the greatest of all the problems in the conservation of natural resources. Productive agricultural soils are by far the greatest of all national assets; for agriculture is the basic industry among all the industries pursued by man. The American people have been blessed with greater national agricultural resources than any other nation, past or present, of the Earth. We have spent a great deal of our national energy and resource-

fulness in overcoming the natural obstacles that stood in the way of our creating real wealth from this potential wealth that nature gave us within the boundaries of our country. We have been eminently successful in the rapid extension of the farm land area of the United States, and our agricultural conditions are now such that we should turn our energies to the problem of conserving the resources that have come down to us from our forefathers. Both city and country need to know more of crop rotation, commercial fertilizers, and the general problem of soil fertility. It is the greatest of all our national problems and yet one that receives the least consideration.

PROBLEMS AND PRACTICUMS

(1) Write a short history of the agriculture in your local county or agricultural region. Ascertain the dates of early settlement, the markets and marketing facilities of early days, the changes in land values that have taken place, changes that have occurred in the crops and systems of farming, the history of the yields of staple crops, and the changes that labor conditions and machinery have effected.

(2) Write an essay discussing modern agricultural conditions in your region, and state the types of agriculture and animal husbandry you regard best suited to your soil, climate and markets.

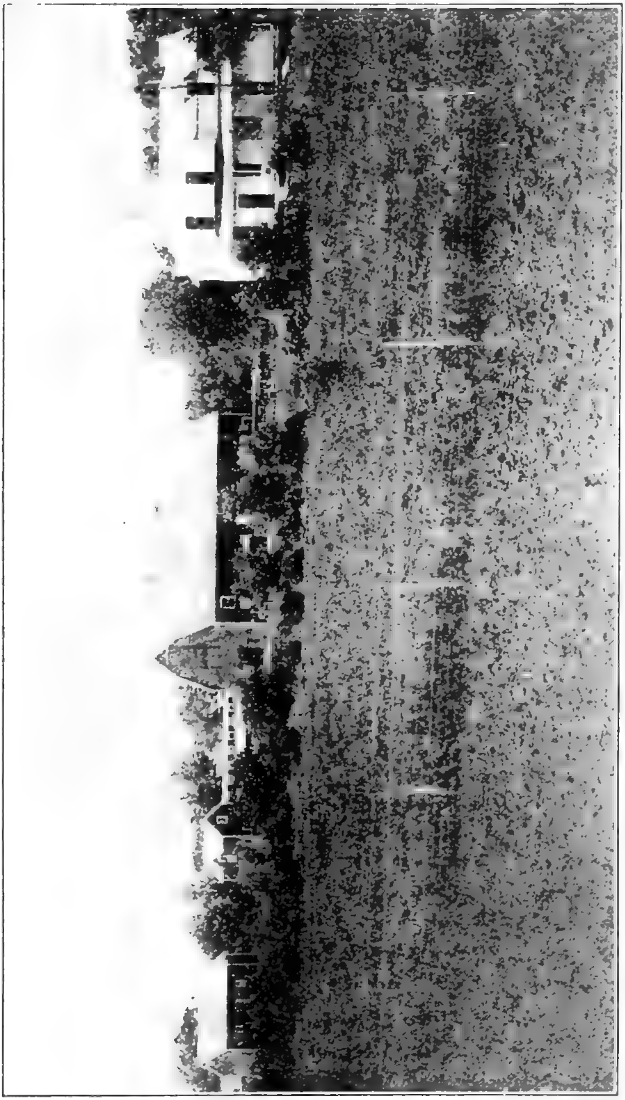


Photo by courtesy C. G. Selvig.

A farmstead and buildings that are typical of the new, diversified agriculture in the Red River Valley.

PART VI

ADDITIONAL FEATURES OF FIELD MANAGEMENT

CHAPTER I

PLOWING PRACTICE

All Soils Cannot Be Plowed Alike. Soils vary so in texture and character of subsoil that the best results are not secured by uniform methods of plowing. Local experience is often essential to knowledge regarding the best plowing practice for a certain soil. As a rule, clay and clay loam soils should be plowed deeper than sandy or sandy loam soils. The sandy soil is naturally porous and too much loosening of the soil is undesirable, as it may destroy good capillary connections in the seed bed. The clay soil, on the other hand, is naturally retentive of moisture and deep plowing will usually benefit aeration and warmth in the soil.

Relatively deep plowing, six to eight inches, has become the standard depth among the best farmers in all the great agricultural regions of the United States. Sod breaking is now commonly done to a depth of five inches, whereas three to four inches was formerly thought to be the correct depth. When land is plowed six to eight inches deep, a much better seed bed is provided for young plants than if shallower plowing is practiced. Deep plowing prevents an excessive run-off of rain water, and also provides a comparatively large soil area in which the roots of young plants may quickly penetrate to absorb moisture and plant food. The movement of air throughout the seed bed is also facilitated when deep plowing is practiced, and air and warmth

are as essential to seed germination and plant growth as moisture. In times of drouth a deep, mellow seed bed is not so likely to bake and dry out as a shallow seed bed especially if fall plowing has been practiced or spring plowed land packed with the subsurface packer. The liberation of available plant food from inert forms in the soil is facilitated when deep plowing is practiced, because more favorable temperature, moisture and aeration are provided for the presence of the soil bacteria that assist chemical changes.

Photo by courtesy St. Paul Machinery Manufacturing Company.

The small gas tractor plow, that can be turned in as small a space as a gang plow with four to six horses, is finding great favor on many grain and corn farms. When properly handled the quality of the work is very high, and the cost per acre less than with the horse plow wherever the annual acreage to be plowed is sufficiently large to justify the investment.

Experience has shown that when deep plowing is contemplated on ordinary prairie or timber clay loam soils in humid regions, on which shallow plowing has been previously practiced, it is advisable to increase the depth of the plowing gradually rather than to increase greatly in one year. It is not unusual for very poor crops to follow a radical change in the depth of plowing. This is almost

always the case if the subsoil is different in character from the surface soil or if tests show the subsoil to be more acid than the surface soil. In semi-arid regions, or on any soil area where the subsoil contains more lime than the surface soil, and where the subsoil is of the same character as the surface soil, a quick change in the depth of plowing will not usually cause poor crops. If it is known that the subsoil is more acid than the surface soil, a quick change in the depth of plowing can be effected without much danger by plowing under green manure crops and also liming the soil to correct acidity. A good top-dressing of manure, together with lime, on freshly turned, deep plowed land, would also overcome the difficulties arising out of a quick change in the depth of plowing.

When the surface soil is stripped from land along a road, it is always noticeable that vegetation does not thrive well on the stripped land for several years thereafter. Soil experts believe this condition of soil sterility to be due to acidity and also to the fact that in humid climates subsoils need aerating and the chemical re-arrangement of matter to place plant food in forms available to crop roots. The many forms of bacteria that live in the soil and that play an important part in the preparation of plant food are not found in quantity in the subsoil. Apparently the necessary conditions for the work of soil bacteria and for the processes that convert inert plant food to available forms are not provided in most subsoils, and thus the soil is "dead" and comparatively unproductive until exposed for some time. Deep plowing may bring "dead soil" into the furrow-slice and thus cause a poor crop by retarding early growth. For this reason it is usually advisable in humid regions to increase the depth of plowing gradually on land formerly

plowed shallow, or to use lime and vegetable matter to give life to new soil brought up from the subsoil.

Subsoiling or Deep Tillage. Theoretically it would seem that, if six to eight inch plowing is better than four inch plowing, twelve or sixteen inch plowing would prove still more profitable. Investigational work and practical plowing experience, however, will not bear out this general theory. There is probably more evidence against deep tillage (over eight inches deep) than there is in favor of it. In certain regions deep tillage is recommended as profitable, while in other regions deep tillage experiments show negative or neutral results, especially if the additional cost of tillage is taken into consideration.

Practically all of the old types of subsoil plows invented in the United States have been discarded by the farmers who have tried them. These plows were run in the bottom of the furrows made by a common moldboard plow and loosened up the subsoil beneath the ordinary furrow-slice. Negative results commonly followed their use or, if positive results were secured, they were not large enough to justify the additional expense.

In recent years a heavy, durable, disk plow has been invented that will cut and invert the soil to a depth of fourteen to eighteen inches, if desired. One disk cuts to the depth of the common plow and the second disk cuts to an additional depth as desired. The soil raised by the disks from the two different soil areas is thoroughly mixed and well pulverized. The cost of deep tillage with this plow is reported to run from $4.00 to $6.00 per acre. Investigational work with deep tillage, as performed by this plow, is very conflicting at the present time, and exact statements about its use cannot be made. Theoretically, it would appear that in the semi-arid regions of the United States deep tillage

Photo by courtesy Duluth and Iron Range Railway.

The heavy construction and strong, sharp disks of the deep tillage plow are of great advantage in subduing new land full of old tree roots and the stubs of brush. With plenty of power it will cut its way through newly cleared land much better than the moldboard brush plow, and will leave a smooth seed bed.

would greatly benefit the soil by increasing its ability to quickly absorb rain water and prevent an excessive run-off or surface evaporation. But investigational work will not bear out the theory. In many cases where deep tillage has been practiced in the semi-arid regions positive results were secured in the wet years and negative results in the dry years. Also in the humid prairie regions of the Middle West the practice of deep tillage has more often shown negative results than positive, especially if the additional cost is considered.

Deep tillage, as practiced with the disk plow, is reported to be profitable in some of the irrigated sections of Texas and also on some of the badly worn, heavy soil areas of the Southern states. Soils having very hard subsoils appear to be benefited by occasional deep tillage. In the Northern

timbered areas of the United States the disk deep tillage plow has been found very useful in breaking wild land. It will cut and tear out brush roots and cover rubbish much better than the moldboard brush plow. In drained swamp areas having a peaty surface soil with clay or marl subsoil it has proved useful in mixing the subsoil with the peaty soil and thus making a good seed bed for farm crops.

It is quite probable that many of the negative results from deep tillage have been caused by bringing up acid subsoil. In fact some authorities state that 90% to 95% of the subsoils in large areas of the humid regions of the Middle West are more acid than the surface soil, and that deep tillage is sure to be unprofitable under such conditions, unless the soil is thoroughly limed to correct acidity. On the other hand, if the subsoil contains more lime than the surface soil, deep tillage will usually prove profitable.*

It appears, therefore, that subsoil acidity is the first point to consider in determining the advisability of deep tillage. If there is an abundance of lime in the subsoil, deep tillage may prove profitable, otherwise negative results will be obtained. If the subsoil is known to be acid and it is thought desirable to plow very deeply to remedy a hard subsoil or to renovate a badly worn soil lacking in organic matter, it should be planned to plow under organic matter and to thoroughly lime the land after plowing. There is not sufficient evidence in favor of deep tillage in the semi-arid regions to warrant the practice. In fact, it is wise, on any soil area, to proceed cautiously with deep tillage. Experiment on a strip of land in one of the fields and, if the results are profitable, the practice can then be extended to all fields. If deep tillage is found profitable, it can be practiced every three to six years

* From investigational work of S. D. Conner, Associate Chemist in Soils and Crops, Agr. Expt. Station, Purdue University, Lafayette, Indiana.

in the rotation, the deep tillage plow being used to turn under a clover or alfalfa sod or a green manure crop.

On farms practicing crop rotation, including such deep rooted legume crops as red clover, alfalfa, or sweet clover, and with thorough plowing to a depth of six to eight inches, it is doubtful whether there is any present or future need for deep tillage. The taproots of alfalfa, red clover, or sweet

Photo by courtesy "The Farmer."

The physical condition of certain types of heavy soil is improved by deep tillage. As a rule, plowing to a greater depth than eight inches is not profitable unless the subsoil contains more lime than the surface soil, or unless the land is limed after plowing in case of soils having acid subsoil.

clover, penetrate deeply into the subsoil and keep it mellow and open for the passage of air and moisture. When these crops are made to occupy the land every three to five years, the subsoil will be kept porous and accessible to the roots of other crops. Deep tillage should be considered chiefly as a corrective measure for soils having a heavy subsoil, or soils that are in a very bad physical condition from long continued cropping without legume crops. There is no evidence to show that deep tillage is sufficiently profitable to supersede ordinary six to eight inch plowing on the vast majority of American farms.

Fall and Spring Plowing. In most regions of the North Temperate Zone fall plowing is preferable to spring plowing for a majority of the farm crops. Weeds can be destroyed to better advantage and the furrow-slice is given time to settle down against the subsoil and to establish good capillary connections for moisture. In semi-arid regions, wherever the soil is sufficiently moist, fall plowing tends to conserve snow moisture during the winter and early spring, because plowed land will absorb moisture more readily than hard, unplowed land. Small grains thrive best on a fairly compact seed bed, and fall plowing provides the desired physical condition in the soil somewhat better than spring plowing. Fall plowing also relieves much of the labor rush that occurs in the planting seasons of spring, and makes it possible for the farm manager to give more careful attention to the pulverizing of the seed bed and to the work of planting. In regions where the growing season is comparatively short, and where the spring season is also short, spring plowing delays seeding, and may cause injury to the crops from a late harvest. Fall plowing is of greater advantage on sandy soils than on clayey soils, because moisture is harder to conserve for crops, and a fall plowed seed bed

has better capillary connections with the subsoil than one that is spring plowed.

With many clayey soils, in regions where spring rains are plentiful, spring plowing is regarded preferable for certain crops, such as corn and barley. The seeds of these crops germinate best and early growth is most rapid, if comparatively warm temperatures prevail in the soil. Spring plowing for heavy soils will usually provide somewhat warmer temperatures than fall plowing, and, when practiced in a region of abundant spring rainfall, the conservation of winter moisture is not important. Spring plowing for root crops, such as potatoes, sugar beets, and mangels, is considered best on types of soil that are inclined to become compact during the winter months, if fall plowed. Deep spring plowing provides a mellower area for roots to develop in than fall plowing, if the soil is heavy and the spring season moist.

If spring plowing is practiced on account of hard, dry soil conditions in the fall or of insufficient time in the fall, rapid evaporation of moisture from freshly plowed land can be easily checked by the harrow and the sub-surface packer. A soil condition in spring plowing similar to that in fall plowing at the spring season can be created with the packer and the harrow. If spring plowing is packed the same day it is plowed, all air spaces will be eliminated from the furrow-slice and the plowing will be crushed down against the subsoil with good capillary connections for moisture. If the packing is followed immediately by surface harrowing whatever moisture is in the plowing will be quite securely locked up. The work of packing can be done satisfactorily with a Campbell sub-surface packer or a common disk harrow with disks set straight ahead. Packing and harrowing spring plowed land in the semi-arid regions, the same day land is plowed, is almost essential to a good seed bed. It

is not so essential to spring plowed land in humid regions, but is, nevertheless, desirable in preparing land for small grains. If clods are thrown up by fall plowing, frost and water are given time to crumble the clods and close up the air spaces; but with spring plowing the case is different, and a spring plowed seed bed is likely to be cloddy and full of air spaces, unless it is packed and harrowed the same day as plowed.

Photo by courtesy Deere and Company.

The two-way sulky plow, equipped with a right hand and a left hand plow, is very useful in doing good plowing on hillside lands. On level lands, also, its use eliminates the many back furrows and dead furrows caused by "plowing in lands" with the common plow.

CHAPTER II

SOIL INOCULATION FOR LEGUME CROPS

Bacteria Essential to Legume Growth. Legume crops attain their greatest development and productivity when they are associated with the nitrogen gathering bacteria. On soils abundantly supplied with nitrogen, phosphorus and lime, they will grow quite well without the aid of the nitrogen gathering bacteria, but full development of the crop stand and of plant growth is not obtained, if the nitrogen gathering bacteria are not present in the soil.

Frequent Lack of Bacteria. In new agricultural regions, as well as old regions, where continuous corn, grain or cotton growing has been practiced, it is not uncommon for soils to be lacking in a supply of the bacteria that commonly live with legume crops. If once these bacteria get into the soil, they will remain there several years (estimated maximum five to six years) without the presence of the legume crop, maintaining their existence on the decaying roots and stubble of the last grown legume crop. But, if no legume crops have ever been grown on the land,

From Bul. 94, Illinois Agr. Expt. Station.
Red clover growing in soil provided with all elements of plant food except nitrogen. Each pot planted with the same number of seeds. The soil in the right hand pot was inoculated with nitrogen gathering bacteria from an old clover field, while none were added to the left hand pot.

or if a long interval elapses between the seedings, it often happens that there are no bacteria in the soil, and, as a result, the crop stand is weak, thin, and of poor growth. It pays, therefore, to give some consideration to the supply of soil bacteria when plans are being made for the seeding of legume crops.

Species of Bacteria. There are many species of bacteria that inhabit the soil and that become parasitic on the legume crops. A few of the most important species are well known to science, but many forms are still but little understood. It is known, however, that certain forms of bacteria attach themselves to certain legume crops only. For example, the bacteria found with the roots of soy beans will not attach themselves to the roots of red clover. Also the bacteria of alfalfa roots will not grow on the roots of red clover, or those of red clover on alfalfa. Thus we know that, if the soil becomes inoculated with bacteria that will aid the growth of one kind of legume crops, they will have no effect on the growth of other species of legumes. The only well known exception to this rule is in the case of alfalfa and sweet clover; for it is known that the same bacteria that live with alfalfa roots are also found on the roots of sweet clover. Except in this one instance, our practice of soil inoculation must assume that each legume crop has its own species of bacteria.

Natural Means of Distribution. The nitrogen gathering bacteria are spread gradually throughout farming communities by the seed, straw, and chaff of the legume crops, to which the small bacteria may adhere. Manure from live stock fed on legumes is also a means for the distribution of soil bacteria. The hoofs of horses, cattle or sheep, the wheels of a wagon, or the plow and harrow may be the means for distributing soil infected with bacteria from one

field or region to another. These ordinary and haphazard means of bacteria distribution are unsatisfactory, of course, when it is desired to quickly inoculate the soil with sufficient bacteria to stimulate the growth of a legume crop.

Artificial Methods of Inoculation. There are two methods available for inoculating the soil of a certain field with bacteria, (1) by the use of laboratory prepared cultures of known forms of bacteria which can be put into water, and that will develop large numbers of bacteria that can be spread over soil areas and harrowed into the soil, and (2) by the spreading of soil from a field where the soil is known to be well infected with the desired species of bacteria. The presence of bacteria in the soil for any legume crop is easily determined by examination of the legume crop roots. If the soil contains an abundant supply of bacteria, the crop roots will be covered with many little nodules or swellings that contain the bacteria.

The first method is unreliable on account of the difficulty of controlling all conditions of temperature, moisture, and food between the time the culture of bacteria leaves the laboratory and the time it gets into the land. Inoculation may be successful and it may not—usually not. The second method has, therefore, come to be relied on chiefly for the inoculation of soil, and, if soil samples are obtained from well infected land, satisfactory results are secured.

In inoculating a soil by means of a soil sample known to contain the desired kind of bacteria all that it is necessary to do is to obtain a load of soil from the infected field of a neighbor and spread this soil at the rate of 200 to 500 pounds per acre over the field on which the legume crop is to be sown, harrowing it in thoroughly. A good plan is to take the soil sample and mix it up thoroughly with barnyard manure, using the manure spreader to distribute the mixture on the

field. This plan provides for even distribution and also provides a supply of available nitrogen for the use of the young legume crop. The best time of the year to inoculate land depends on the season when the legume crop is to be sown, whether spring, midsummer, or autumn. The sample of infected soil should be worked into the soil just prior to seeding.

In inoculating a field for alfalfa the inoculated soil sample should be secured, if possible, from a neighbor's successful alfalfa field. If no neighbors have alfalfa fields, a sample of soil may be shipped in from any distance where freight rates do not make the cost prohibitive. Also a soil sample may be used from roadside patches of sweet clover. One of the very best methods for inoculating the soil for an alfalfa crop is to sow a green manure crop of sweet clover one or two years prior to the time when it is planned to seed down to alfalfa. Sweet clover usually catches more easily than alfalfa. This practice will aid in inoculating the soil as well as in putting the soil in a clean, rich, mellow condition for the young crop of alfalfa.

Similar methods should be employed in inoculating soil for the clovers and for soy beans, remembering that the safest plan is to get a soil sample from a successful field of the same species of legume crop. If the soil is known to be supplied with legume crop bacteria, as evidenced by root nodules, there will be no further necessity for inoculation, even though the same legume crop should not reappear in the rotation for several years. It does not usually pay to inoculate the soil for cowpeas, vetches, or field peas. The bacteria for these legumes follow the seeds everywhere. Even with these crops, however, it is very noticeable that the second or third crop growing on infected land is better than the first crop growing on uninfected land.

A very cheap, and often successful, plan for inoculating soil is to anticipate the seeding of a certain legume meadow or pasture crop by prior light and scattering seedings of legume seeds with such staple crops as corn, cotton, wheat or oats. Such light, scattering stands of the legume as may thus develop, are plowed under, and soon a sufficient supply of bacteria will accumulate to provide the conditions for a dependable stand of the desired legume crop.

Other Conditions Necessary for Legume Growth. Failure to get a good stand of such legume crops as alfalfa, red clover, or alsike clover, is often due to a poor physical condition in the seed bed. The seeds of these plants are very small and also covered with an oily hull. Good germination and strong growth of the young plant cannot be had in a rough, lumpy seed bed. The seed bed should be well pulverized and compact for this kind of seed. In the clover growing regions of the Upper Mississippi Valley, experience has shown that thoroughly disked corn land will provide better seed bed conditions for a clover seeding than spring plowing, for example. Seeding, also, should be shallow to get best results with small seeded legumes. Poorly drained land is also the cause for much legume failure. None of the standard American legume crops, except alsike clover, will stand wet soil.

Insufficient supplies of lime and phosphorus in the soils of old farms are often the cause for poor stands of legume crops. (A discussion of this feature of legume growing will be found on page 306.)

Note: For complete information on the subject of soil bacteria and legume crops see Bulletin 94, Illinois Agr. Expt. Station.

CHAPTER III

SEED SELECTION

Heavy Seed is Good Seed. Seed selection is an important factor in getting a full crop. Light weight seed, diseased seed, and seed with weak germinating power, retard greatly the early growth of plants. A quick, strong start with any crop means extra bushels at the harvest. The runt pig never makes the gains and the profit that the fast growing young pig makes, and similarly the runt plant never catches up to the plant that started its life quickly and with the full measure of early growth. Heavy seed is usually good seed, because it has a strong, vital germ, and a bountiful supply of food to nourish the young plant until it can develop a root system and gather its own food. Light seed is poor seed for the opposite reasons.

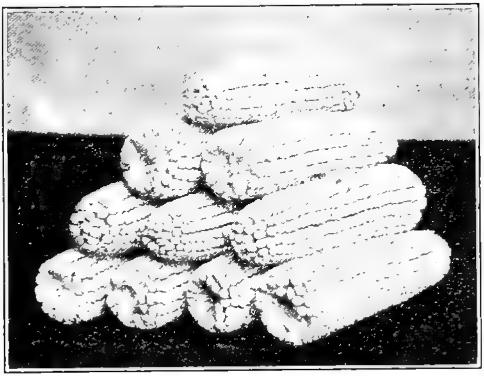


Photo by courtesy "The Farmer."

Good ears of seed corn are those that are cylindrical, straight rowed, many rowed, well filled at the tip and butt, and having as deep kernels and as high a proportion of grain to cob as is consistent with the climate.

It pays well to select good seed. The farmer who sells his best grain and takes his seed from whatever is left puts a severe handicap on his crop. It is just as important to save the best seeds for planting the crop as

to save the best heifers for breeding purposes. The best farm practice is to save the seed first and sell the balance of the crop.

How to Select Good Seed. Numerous machines and devices are available to grade and select the heavy, plump seed that makes good seed. The fanning mill is the most common and practical machine for this purpose. Good seed can be selected out of almost any grain bin, if the fanning mill is used correctly. There is always a certain per cent of good, plump seed in any grain sample that can be separated from the seeds of poor quality. Simply screening the grain, however, will not give a good seed selection. Large seeds are sometimes swollen and moldy and, therefore, not the best of seed. Screening will remove the chaff, very small seeds, and most of the weed seeds, but it will leave many weak, light seeds in the cleaned seed. The screens must be supplemented with a strong wind blast, regulated according to the kind of seed, into which the seed is dropped, and by means of which all light weight seeds are carried over. The side shake fanning mill with a long drop between the hopper board and the weed screen is the best type of machine to select seed grain by weight. But all fanning mills can be so adjusted as to put this principle into effect, if enough thought and care is given to the adjustment.

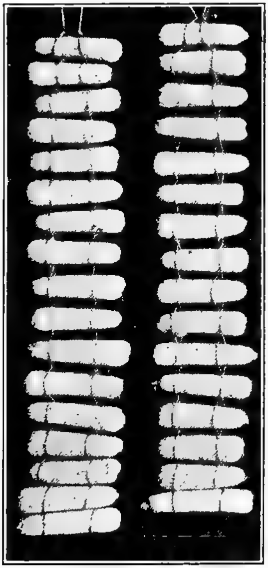


Photo by courtesy "The Farmer."

Seed corn hung in such a manner as to permit free circulation of air around the ears causing rapid and thorough drying.

Special Care Necessary for Seed Corn. A full stand of strong growing corn is of especial importance to the crop grower. An incomplete stand is always revealed at husking time, and in the Northern limits of the corn belt a slow starting, weak crop, may get caught by early frosts in the autumn. Good, strong, vital seed corn cannot be had by merely grading the shelled seed. The sensible, practical way to provide good seed corn is to give a thought to the selection and curing of the seed in the autumn, and then to eliminate all risks from weak seed by testing every individual ear of corn for germination before the seed is shelled and run into the planter. This is easily done by making a germination box two feet square and six inches deep. Rule off a cotton cloth into one hundred squares two inches by two inches and give each square a number. Place the checkered cloth over moist sawdust or bran in the box. Take as many ears of seed corn as there are squares on the cloth and tag each ear with a

Photo by courtesy "Farmer and Breeder."

Selecting the sound matured, and well formed ears of corn for seed. Field selection of seed corn, prior to killing frosts, is an important feature of getting seed with high germinating power.

number. Now pull out six to ten kernels of corn from the various places on the ear (except tip and butt that should be discarded) and place on the cloth square of corresponding number. Cover the box with a flannel cloth and place in a warm room. Note the per cent of germination on each square and discard all seed ears that do not give perfect and strong germination.

After seed is shelled from selected ears it should be graded with the "corn grader," the sieves of which will take out all irregularly formed kernels. Graded seed will run more smoothly through the corn planter than ungraded.

If seed corn is selected by this method, the harvest will surely reward the efforts; for the stand will be nearly perfect, and the early growth strong quick and uniform.

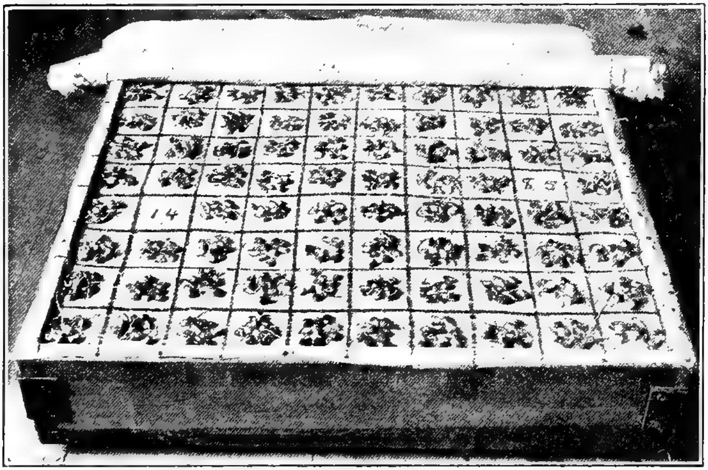


Photo by courtesy "The Farmer."

A germination box for seed corn by means of which a test can be had on individual ears. The ability of seed corn to germinate varies greatly with different ears. The only way to make sure of a full stand of corn is to test the seed from every ear.

CHAPTER IV

IMPROVED CROP VARIETIES

Pure Seed of improved crop varieties is to be greatly preferred to mixed seed of common varieties. Pure seed gives a crop that markets to better advantage than a crop from mixed seed, because the quality is more uniform. Not only does pure seed market to better advantage than mixed seed, but it also results in better crops when used for seed purposes. Pure seed will germinate more uniformly than mixed seed and thus cause evenness and uniformity in the crop stand and crop maturity.

Improved Varieties, also, have greater productiveness, as a rule, than common varieties, and often have other desirable characteristics, such as earliness and resistance to disease or drouth. Plant breeders have accomplished wonderful results in so breeding and selecting farm crops as to fix desirable characteristics of productiveness, uniformity, earliness, and resistance to disease. An improved crop variety may yield as great an increase over the yield of a common variety as that of a well bred dairy cow over that of a scrub cow.

The United States Department of Agriculture, as well as the various State Agricultural Experiment Stations, have made available to the farmers of the United States a great number of new and improved crop varieties adapted to all the various agricultural regions of the country. New and valuable crops, such as durum wheat, bald barley, Kafir corn, proso millets, Sudan grass, and hardy alfalfa, have been introduced from foreign countries and distributed over the United States. The plant breeders have developed

Photo by courtesy H. L. Bolley, North Dakota Agr. Expt. Station.
Two plots of flax growing on land infected with flax wilt. The right hand plot is a variety that is immune to the disease.

new and productive varieties of corn that have made possible a great extension of the American corn belt into regions hitherto regarded as unfavorable for corn. Varieties of flax have been developed that are immune to flax wilt, and progress is being made in breeding crops immune to rust and other diseases. The length of cotton staple has been increased; size and smoothness of root crops improved; earliness developed in certain grain crops; and numerous other improvements made to crops that add to their commercial value.

It is profitable for the farmer to use these pure, improved varieties that have resulted from the work of the trained plant breeder. It is not advisable to use seed of an improved crop variety brought from a long distance and from a climate differing from the local climate. When it is deemed advisable to introduce seed of a new variety, it is best to obtain it from local sources so far as possible and on the advice of the local Agricultural Experiment

Stations. Seed brought from a great distance may give a poor crop on account of variations in climatic conditions.

Maintaining the Pureness and Productivity of the Improved Variety rests mainly with the farmer himself. Careful selection and care of the seed from year to year will prevent admixture and running out of the variety, while the converse will take place, of course, if the seed is not properly selected and cared for.

There is no doubt that varieties of grain, corn, potatoes, or other crop, run out in time, so that the yield is impaired. This result is generally due to insufficient attention to seed selection. It takes but a few years to impair the yield of corn and potatoes, if seed selection is neglected.

On the other hand, if seed corn ears are selected every year to a type considered best for the local conditions, the productivity of the variety will increase rather than diminish with the passing years. Likewise with potato varieties, high yielding plants should be made the basis for selection rather than individual potatoes taken from the bins. With such methods of selection the variety productivity will not run out. Maintaining the variety productivity of such crops as corn and potatoes is greatly aided by the use of seed plots where careful attention can be given to the selection of the seed.

When the original seed stock is of a pure, improved, productive variety, there is usually more to be gained by careful selection of the acclimated, localized variety than by a frequent change of varieties. New varieties are advisable only when known to have special characteristics of great value. It is always wise to proceed slowly with the substitution of new varieties for those that have been long in use locally, and to give the new variety a small field trial before adopting it on a large scale.

Harvesting improved, pedigreed wheat at the Minnesota Agricultural Experiment Station. From the breeding plots the best strains are selected and the seed increased for distribution to farmers. It is profitable to use improved varieties of farm crops.

CHAPTER V

FUNGUS DISEASES

Flax Wilt. This disease can be kept out of the land, if treated seed is always sown, if infected straw is burned and not used for bedding, and providing threshing machine dust from an infected crop is not blown over the land. The flax wilt fungus will live in the soil for six to ten years and attack a crop of flax at any time when sown. Treating the seed is but one of several precautions to use in keeping the disease out of the land. The disease is carried over from one year to another on the seed, straw, and stubble. Treated seed on clean land prevents any loss from wilt; treated seed on infected land will check the loss, but not entirely prevent it; while untreated seed on infected land gives the disease every opportunity to cause crop loss. Treating the seed, when the seed is secured from other farms, is profitable insurance against infecting the land.

Flax seed cannot be properly treated by machinery. The work must be done by hand methods. The seed should be carefully fanned before treating to remove all badly diseased and weak seeds. Spread the seed to be treated on a wagon canvas or cement floor. Prepare a solution of weak formaldehyde in a pail or tub (one pint or pound of 40% pure formaldehyde to forty-five gallons of water). Spray this solution over the seed very slowly with a compressed air sprayer such as is used for potato and cabbage spraying. (A small knapsack sprayer can be bought for $3.00 to $5.00.) Shovel the grain over and over while spraying. Apply very little of the solution—just enough to merely dampen the seed. Soak the grain sacks, to be

used in taking seed to the field, in the solution and hang up to dry out, or, better, spread the sacks over the pile of seed. Treat the seed six to twelve hours before seeding. Sprinkling the solution on flax with a common sprinkling can is very likely to cause caked seed. It is better to use the compressed air sprayer and be sure of having seed that will run smoothly through the drill.

Stinking or Covered Smuts of Wheat, Barley, Oats and Rye. The stinking or covered smuts of wheat, barley, oats and rye, are carried over from one year to another on the seed grain only. Properly treated seed gives an absolutely clean crop, for this fungus disease cannot be transmitted to a crop from the soil. Perfect control of the disease

Photo by courtesy H. L. Bolley and M. L. Wilson, N. D Agr. Expt. Sta.

Treating seed flax with formaldehyde to destroy the spores of the flax wilt fungus. The formaldehyde should be applied with a compressed air sprayer to secure an even spread of the liquid and prevent caking of the seed.

can be had by so treating the seed grain as to destroy the vitality of the smut spores (small, black seeds) that adhere to the seed grain.

The first step in freeing seed grain from smut is to thoroughly fan the seed in order to remove all smut balls, chaff, and weak seeds. Then prepare a solution of formaldehyde in a tub or pail, using one pint or one pound of 40% pure formaldehyde to forty-five gallons of water. If large quantities of seed are to be treated, the smut machine can be used to advantage. By means of worm carriers or elevators these machines move the seed quickly through the formaldehyde solution, drenching the seed thoroughly, and running it out to a pile or into sacks. Seed can also be thoroughly treated by piling it on a canvas or clean floor and sprinkling the solution over the seed with a common garden sprinkling can, shoveling the seed grain rapidly while sprinkling. Apply only enough of the solution to dampen the seed. Soak the sacks in the solution that are to be used in taking the seed to the field and spread the sacks over the pile of seed grain to dry and to hold the formaldehyde gas in the seed mass. Treat the seed at least four or five hours before seeding.

Treating seed grain of wheat, barley, oats, and rye, causes the seed to swell slightly by reason of the moisture absorbed. The drill should, therefore, be opened a little wider to get in the standard amount of dry seed. An increase of 15% to 20% in the amount of treated seed over dry seed is sufficient to equalize the seeding rate to the standard amount.

Loose Smut of Oats. This fungus causes very heavy damages in oat crops. The smut spores (seeds of the fungus plant) are distributed by the wind prior to harvest as well as spread through the grain by the threshing machine. The

disease is carried over from one year to another by the seed grain only. Crop infection does not come through the soil. Perfect control of the disease can be had by seed treatment. Use the same methods of treatment as described for the stinking smuts of the cereals.

Loose Smut of Wheat and Barley. The loose smuts of wheat and barley cannot be successfully treated on the farm. The fungus spores are very resistant to formaldehyde and other chemical treatment. The loose smut of barley causes considerable damage, but that of wheat, comparatively little. If these smuts get into the crop, the practical remedy is to change seed at once, getting it as near home as possible and free from these smuts. Another way is to grow a small seed plot and hand pick the diseased heads of grain before harvest. This is not a practical method, however, for the ordinary farmer.

Corn Smut. This smut rarely causes heavy damage. It cannot be controlled by seed treatment, because the fungus spores are very resistant to chemical treatment and because the disease can be carried over in the soil. Hand picking and burning of the diseased plants is the only remedy. If smutty corn gets into the manure pile the spread of the disease is greatly facilitated. Care should be exercised to keep smutty corn away from the manure pile and to throw it to one side when cutting ensilage.

Kafir Corn Smut. This smut does not cause heavy damage to crops. It can be controlled by soaking the seed for twelve hours in a solution of one pint or one pound of 40% pure formaldehyde to sixty-two gallons of water.

Potato Scab. This disease often causes very great damage to both the yield and quality of potatoes. It is carried over from one year to another on the seed potatoes as well as through the soil. Seed that is free from scab will

not give a clean crop on land that is infected with scab. Crop rotation is absolutely essential to the minimizing of loss from scab. Fresh manure on potato land is also conducive to the spread and propagation of scab. It is best to use rotted manure on potato land and to put the fresh manure on corn land. If fresh manure is to be spread on potato land, it is best to spread it in the fall and early winter and permit frost and water to decay it before the planting season.

Treating scabby potato seed will give a clean crop, if the soil is not infected. It is regarded best to treat the seed before cutting. Soak the tubers two hours in a solution of one pint or one pound of 40% pure formaldehyde to thirty gallons of water. Large quantities of seed can be very cheaply treated with little labor, if adequate equipment is provided and the work planned properly. The cheapest and handiest equipment on the average farm is provided with a small block and tackle, hitched to a convenient rafter or beam, for lifting the sacks of tubers, and as many water tight barrels as are needed to keep seed treated ahead of the cutters. Fill the barrels two thirds full with the formaldehyde solution and drop a sack of tubers into each barrel to soak for two hours. After treatment spread out the tubers to dry for a short time before cutting. This is desirable, but not essential. Put the treated and cut seed into sacks that have been soaked in the solution, otherwise the seed may become infected from the sacks. Change the solution in the barrels occasionally as it soon becomes dirty and foul. Plan the treating and cutting so as to get the seed into the ground in as fresh a condition as possible. This, also, is desirable, but not essential.

Potato Blight. This fungus often causes very great damage to potato crops by attacking the leaves, stems and

tubers, and so weakening the vitality of the plants as to check full maturity and development. At one or both of two seasons there may be an attack of blight, (1) early blight that comes shortly after the crop is through the soil and prior to blossoming, and (2) late blight that usually attacks the crop after blossoming and when the tubers have begun to form. Early blight attacks the leaves only, entering the leaf tissues usually through holes made by insects. Late blight attacks the leaves, stems and often the tubers as well, causing decay of plant tissue and premature death. Both diseases spread by means of spores (fungus seeds) which germinate on the potato leaves or stems and from which a tiny parasitic plant develops that gains entrance into the plant tissues and saps the strength of the host plant.

There is no cure for the potato blights, if they have once

Photo by courtesy New York Geneva Agr. Expt. Station.

Potatoes sprayed with Bordeaux Mixture to prevent blight, and one row not sprayed. When blight attacks the potato plant the vines die early and the yield is light. Sometimes the late blight works its way into the tubers and causes rot.

gained entrance to the host plant. Measures can be taken, however, to prevent the fungus from gaining entrance to the leaf tissues. This is accomplished by spraying the potato plants with Bordeaux Mixture and thus coating the leaves with a film of protective material. Spraying must be done with some form of a compressed air sprayer that atomizes the solution into a fine spray. Gravity sprinklers will not perform this work successfully.

Bordeaux Mixture is a combination of copper sulphate (bluestone), quicklime, and water. The standard formula for potato blight spraying is 3 lbs. copper sulphate, 4 lbs. lime, and 50 gallons of water. The solution should be made in wooden receptacles, because the copper sulphate will badly corrode iron, tin, and zinc receptacles. The materials should not be put into one receptacle simultaneously. Three receptacles should be provided, one for a stock solution of copper sulphate, one for slaking the lime, and a third in which to combine the materials for use in the field. Weigh out a definite amount of copper sulphate and tie it up in a clean grain or salt sack. Hang this sack in a receptacle containing one gallon of water for each pound of copper sulphate and leave it there until all the copper sulphate has been dissolved. In a second receptacle slake the lime and make a milk of lime, using one pound of lime to one gallon of water. Into the third receptacle pour from the stock solutions of copper sulphate and lime sufficient amounts to dilute in the proportions of three gallons of copper sulphate solution and four gallons of milk of lime to 43 gallons of pure water. This gives a dilute solution known as Bordeaux Mixture containing three pounds of copper sulphate, four pounds of quicklime, and fifty gallons of water. In mixing the solution for field use put in the milk of lime first and then add the copper sulphate solution.

Spraying machines should have the tank made either of wood or copper, as steel or zinc tanks are quickly corroded by the copper sulphate.

In spraying potatoes for early blight the work of spraying for the potato beetle can be done at the same time. Add Paris Green to the Bordeaux Mixture at the rate of one pound to one hundred gallons of water.

Sweet Potato Black Rot and Stem Rot. Soak the seed in the same manner as for potato scab. Change location and soil of the hotbeds occasionally. Drench slightly diseased hotbeds with a solution of one quart of formaldehyde to fifty gallons of water, using one gallon of the solution to each square foot of surface in the hotbed. Drench in the fall or early spring and do not plant until the odor of formaldehyde has entirely disappeared from the soil of the hotbed. Crop rotation is essential to keep land free from this disease.

Tobacco Root Rot and Bed Rot. Drench the seedling bed in fall or early spring with a solution of one quart of formaldehyde to fifty gallons of water, using a gallon of the solution to each square foot of space in the seed bed. Do not seed until all odor of formaldehyde has disappeared from the soil.

CHAPTER VI

WEED ERADICATION

Continuous grain cropping, cut-and-cover plowing, non-use of cultivated crops and grass crops, and non-use of the fanning mill give noxious weeds every opportunity to accumulate on the farm and to infest the land. Conversely, rotation cropping, including grass crops and cultivated crops, good fall plowing, careful fanning of all seed grain, grass headlands along fence lines, and the keeping of live stock, particularly sheep, on farm land, provide conditions that prevent noxious weeds from infesting the land. There are no weed problems associated with good farming, only with the shiftless type of farming. Weed eradication, in a nutshell, is good farming.

In the cleaning up of a weed infested farm it is well to know something about the life habits of the noxious weeds, as well as the best methods for quickly eradicating them. In the following paragraphs the life habits of a few of the most important types of noxious weeds are given as well as suggestions for eradication.

Weed eradication depends on three important principles, (1) checking the production and distribution of seed, (2) weakening the vitality of weed roots by cutting off the leaves and stems (the stomach and lungs) of the plant or shading and crowding the weed plant with a quick growing crop, such as buckwheat, hemp or clover, and (3) the actual uprooting of the weed plant with tillage implements. By keeping these principles always in mind, and with a knowledge of the life habits of any weed, it is possible to devise numerous methods for cleaning up foul land.

Annual Weeds that infest farm lands in quantity are wild mustard, wild oats, kinghead or giant ragweed, and corn cockle. All of these weeds grow up, produce their seed, and die down in one year. Each weed crop comes up annually from the seed. There are no perennial roots to contend with. Checking the production and distribution of seed is, therefore, the method of attack.

Wild Mustard seeds profusely from June until October. The seeds are very oily and will stay dormant in land for fifteen to twenty years, if buried too deep to germinate. Mustard seed harvested with grain crops can be easily removed with the fanning mill, but it is nearly impossible to remove it from grass seeds. The quickest and best method for checking early season seed production in grain fields is to spray with a solution of iron sulphate, using seventy-five to one hundred pounds of iron sulphate to fifty gallons of water. Iron sulphate costs about $15.00 per ton and it takes about fifty gallons per acre for badly infested land. The solution can be applied with a regular potato sprayer with the nozzles set close together so as to cover the land evenly, or with a special weed spraying machine. Iron sulphate will kill the mustard plants, but will not injure the young grain. The spraying should be done before the mustard has come into blossom.

Tillage methods may also be used to eradicate mustard. Disk grain stubble immediately after harvest to induce fall germination of seed. Late fall plowing will then bury the young plants. In the following spring disk and harrow the land to destroy other young plants. Defer grain seeding until late in the spring, sowing barley. Harrow the land continuously until the grain is three or four inches high. This will kill many mustard plants and will not injure the grain, if the harrow teeth are slanted backwards.

Cultivated crops, hand hoeing, and hand pulling, are useful in checking the growth of mustard seed. Care should be used also about locating threshing machine settings of mustard infested grain in or near cultivated fields, as mustard patches often start in fields from infested straw piles.

Wild Oats mature their seed very quickly and shed seed on the land prior to small grain harvest, particularly in case of wheat, late oats, and late sown flax. The seed can be separated from wheat, rye, flax, and barley with the fanning mill, if proper adjustment is made and a strong wind blast used. It is difficult to separate it from oats, but nearly complete separation can be made, if a strong wind blast is used and if the grain is run through the mill several times.

Avoid feeding unground, infested oats to horses, especially during seasons of working the land. Wild oats will pass through the digestive organs of the horse and spread from droppings on the land. It pays to grind infested grain used for feed.

Plan to seed winter rye or early barley on infested land, as these crops mature earlier than wheat and oats and thus more of the wild oat seeds can be removed from the land in the crop and then fanned out of the seed.

Disk or shallow plow infested grain land immediately after harvest and thus induce fall germination of seed. Late fall plowing will then kill the wild oat crop.

Seed a catch crop of rape or clover with a grain crop and pasture the land closely after grain harvest, with sheep, if possible.

Kinghead or Giant Ragweed grows profusely only on rich, moist land. Seed matures late in the season and is often harvested in quantity with small grain crops. The seeds are heavy and of the same size as wheat, barley and

plump oats. Seeds cannot be separated from small grain with the fanning mill. Separation can be made by immersing seed grain in water and skimming off the kinghead seeds that will float to the surface.

When seed grain becomes badly mixed with kinghead the best plan for eradicating the kinghead is to change seed and to procure clean seed from a neighbor or some farm in the same county. Also use the scythe and mower to cut down all kinghead in barnyards, gardens, and along fence lines. These practices, when accompanied by clean plowing and thorough tillage, will quickly clean the land from this weed. It is one of the most easily controlled weeds that accumulate on a grain growing farm.

Corn Cockle flowers and matures its seeds almost contemporaneously with wheat and oats. The seed is heavy and of about the same size as wheat, barley, and plump oats. It cannot be separated satisfactorily from seed grain with the fanning mill. Special cockle mills will take out a large part of the cockle seed, but not all of it. Cockle seed does not shatter on the ground prior to grain harvest as in case of mustard and wild oats. The greater part of the seed crop is harvested with the grain crop. Clean seed grain will give a nearly clean crop.

Changing seed in order to get cockle free seed is the surest and easiest method for eradicating cockle. Hand hoeing, hand pulling, and cultivated crops are also useful in quickly eradicating this weed

Biennial Weeds complete their lives in two years. During the first year the plant develops a taproot that is filled with food material for the plant's growth the second spring. From this taproot, and the crown at its top, the plant starts growth the second year, and a seed crop is produced after which the plant dies and further propaga-

tion depends on the seed. Typical biennial weeds are the bull thistle and burdock. Eradication depends mainly on checking seed production.

Bull Thistle seed is small, light, and produced in great quantity. Feathery tufts of hair attached to the seed aid in its distribution by the wind. The bull thistle often accumulates in great numbers along roadsides and in pastures and meadows. It rarely appears in cultivated fields in sufficient quantity to be troublesome, because plowing and tillage interrupt its two-year life. Mowing the plants with scythe or mower in grass lands and along fence lines and roadsides will soon exterminate the bull thistle. Seeds of the bull thistle are frequently found in clover and grass seeds. They are light and easily separated from standard grass seeds with the fanning mill.

Burdock flowers in late summer and produces seed in the early autumn of the second year of its life. The seed is distributed chiefly by sheep, horses, and dogs, on whose wool, tails or hair the burs adhere. The burdock rarely appears in cultivated land as tillage interrupts its life. It often accumulates in quantity in meadows, pastures, gardens, orchards, and along fences and roadsides. Frequent cutting with the scythe or mower to prevent seeding will quickly eradicate this weed.

Perennial Weeds die down every year above ground, but the roots never die when undisturbed. These weeds seed annually. They are introduced into cultivated fields by the seed or by portions of the roots that have bud-joints from which new plants develop. Noxious perennial weeds are very difficult to eradicate, because not only seed distribution but also root development and distribution must be contended with. Typical perennial weeds are Canada thistle and quack grass.

Canada Thistle flowers from early summer until early autumn and matures most of its seed in midsummer. The seeds are small, light, and have feathery hairs attached that greatly aid in wind distribution. The seeds of Canada thistle are often found in clover and grass seeds and great care should be used in purchasing grass seeds to see that they are pure and clean. Seed should always be fanned when bought direct from farmers in districts known to have Canada thistle.

The roots of Canada thistle will run two feet deep in mellow soil and laterally for four feet or more. The roots are jointed and young plants arise from these joints at frequent intervals. From one parent plant an area of ten to thirty square feet will become infested in one or two years from the spread of the root system. The roots are very persistent, frequently jointed, and full of starch to give life to bud-joints. Tillage that chops up the roots and spreads the divided roots over cultivated land will quickly spread the pest.

Eradication of Canada thistle should proceed along the lines of (1) checking the wind distribution of seed, and (2) weakening the root vitality so that the roots may be destroyed by tillage. In grain growing districts, when the first small patches appear, they should be kept mowed down closely all summer to prevent seeding and to weaken the roots by cutting off the leaf and stem of the plant. At this stage of the thistle crop development it will pay well to keep after the thistle patches in the grain with a scythe and never permit the plants to get any growth above ground. After grain harvest the mowing of the thistle patches should continue until late autumn, if necessary, and then a deep plowing in late autumn will throw up many of the weakened roots to the killing action of frost.

If the thistle crop development, under strict grain grow-

ing, has proceeded to the point where the thistles are all over the land, it is best to take quick and decisive action with a bare fallow on the areas worst infested. Either of two practices can be followed, by means of the bare fallow, to give the land a thorough cleaning: (1) If there is sufficient labor and horse power on the farm, thistle infested land should be constantly mowed all the spring and summer months. If this practice is followed, the thistles must be mowed so often and so closely as to absolutely prevent any leaf and stem growth. In a warm, rainy season, mold will often get into the cut thistle stems and rot out the crowns of the plants, and, even if mold does not work injury, the vitality of the roots will be greatly injured by this constant mowing, and seed distribution will also be checked. In the late autumn plow the land and harrow thoroughly in two directions with a spring tooth harrow set deep. This will lift out many roots, when, if very thick, they can be raked up or left on the surface to the killing action of frost. (2) Permit the thistles to grow undisturbed on the fallow land until they come to blossom. Then plow deeply, using a coulter to insure a clean plowing job. Harrow thoroughly for the balance of the season with a spring tooth harrow. Should the season after plowing be very wet and it appear that the thistles are not under control by harrowing, mow them down constantly and plow deeply again in the late autumn. In most cases, however, plowing under the thistle crop at flowering time, followed by thorough spring tooth harrowing, will give the thistles a death blow.

Fallowed thistle land should be followed with a cultivated crop such as corn, if possible. Check rowed corn and cross cultivation are, of course, preferable to drilled corn and one-way cultivation, but a follow crop of fodder corn or potatoes is much better than a follow crop of small grain.

A cultivated follow crop with some hand hoeing or cutting will put an end to the thistles, if the work is thoroughly done.

Beginning with a fallow year and following with a three-course rotation of barley, clover and corn, will surely put an end to Canada thistles on any land, if the work is thoroughly done. The barley land should be thoroughly harrowed in the spring before seeding, to set back any thistles. Sow clover heavily with the barley (6 to 8 lbs. per acre). The clover will shade the land and crowd the thistles hard during its occupancy of the land, and the two cuttings of clover will prevent all seed distribution. Plow the clover land deeply in the autumn. Frequent cultivation of the corn with some hand hoeing of scattering plants will effectually finish the task, and four years of such cultivation will usually yield more revenue than four years of continuous grain growing on thistle infested land.

Quack Grass is the most difficult of all noxious weeds to contend with, on account of the great persistence and recuperative power of its underground stems. These stems run in all directions in the furrow-slice and are thickly jointed. Any stem portion having one of these bud-joints will produce a plant, if placed in moist, warm soil. These underground stems will dry out until apparently dead and then come back to life again with the first rainfall. Tillage implements are likely to drag these stems over land and hasten the spread of the weed.

Quack grass flowers in early summer and ripens its seeds in midsummer. Fortunately the seed does not easily shatter and is easily removed from the land when grain crops are harvested. Most farms become infested, however, by means of the seed. Threshing machines spread it, and much grass seed, especially brome grass seed, is likely to be foul. It cannot be removed from brome grass with the fanning mill,

but is easily blown or screened out of clover, alfalfa, timothy, and small grain seeds. The seed of quack grass is from one fourth to three eighths of an inch long, narrow, and light brown in color. It is usually bearded, but not always. The greatest care should be used not to seed down land with seed containing even a few seeds of quack grass, for, if once started, it brings a train of trouble in its wake.

Some wit has said the "best way to get rid of quack grass is to seed the land to winter rye and sell the land with the crop thrown in for good measure." This plan may solve the quack grass problem by avoiding it, but it does not help the real farmer and home maker. Unfortunately quack grass is a far worse problem on rich land than on poor land, and failure to eradicate it on good land puts the good land back to second or third quality land.

Delay in attacking quack grass is only piling up trouble and heavy expense for the future, for, if once started in rich land, it spreads like wildfire under ordinary tillage methods, especially with continuous grain growing. The time to attack quack grass most successfully is when it first puts in its appearance in small, round patches of thick sod. At this stage it can be easily smothered by covering with tar paper fastened down with earth and stones. A small investment in tar paper and time at this stage of development will save hundreds of dollars as compared to neglecting it until it spreads badly. The covered patches need careful watching to see that the grass does not creep out under the tar paper. Follow the smothering of the patches with deep plowing and thorough spring tooth harrowing, or, better still, put in a few days working over the smothered patches with a manure fork and sift out the weakened roots. This will put an effectual crimp in the quack grass at the outset.

If quack grass has spread beyond the early small patch

stage, it is best to resort to the bare fallow at once, rotating the fallow over the infested land so as to have but a part of the land idle in any one season. In fallowing the infested land do not disturb the quack grass in the spring and early summer, and then plow deeply when the grass is about ready to flower. This plowing will catch the crop at a weak place in its growth, because it will have given up much of its root strength to the production of seed, and, also, because, in regions where quack grass flourishes the best, the season after flowering is hot and comparatively dry. After plowing, run a sub-surface packer or disk harrow (with the disks set straight ahead) over the land to pack down the plowing, close up air spaces in the soil, and assist the work of suffocating the crop. Thoroughly harrow the land for the balance of the season with a spring tooth harrow, and, if the roots are pulled out in quantity, it is a good plan to rake them up and burn them. Another good plan is to put on a thickly sown buckwheat crop after the midsummer plowing that will smother some of the quack grass and give an income from the land. In either case it is best to follow the fallow year with a corn crop. Ensilage or fodder corn is excellent for this purpose, because it can be sown much later than field corn and thus give an opportunity for semi-fallowing in the spring.

A two-year rotation of fodder corn and winter rye gives a good opportunity to attack the quack grass. Seed the winter rye on the corn land well plowed and harrowed to remove as many grass roots as possible. After rye harvest, plow deeply, pack the plowing, and fallow for the balance of the season with thorough spring tooth harrowing. A second plowing late in the autumn might pay on land very badly infested. Plant the fodder corn thickly in early summer, harrowing the land often with the spring tooth harrow during the spring. If harrowing fails to check the grass

growth, plow deeply in late spring just prior to planting the fodder corn.

In cultivating corn or other crops on quack grass infested land the cultivation should be shallow and very continuous. The Tower surface cultivator is an ideal implement for this purpose. The value of shallow cultivation lies in the fact that it does not root up and spread the jointed roots of quack grass, but thoroughly kills all surface vegetation and thus weakens the vitality of the roots.

Sheep are useful in eradicating quack grass. Badly infested land can be seeded down to clover and timothy, the first crop cut for hay, and then pastured closely with sheep for the balance of the first year and for one or more years following, after which deep plowing, thorough harrowing, and a year of ensilage or fodder corn, well cultivated, will give the crop of quack grass a severe setback.

PROBLEMS AND PRACTICUMS

(1) What do you regard as the proper depth to plow land in your community? State reasons.

(2) What is the cost of plowing an acre of land with a 14 in. walking plow and two horses; with a 16 in. sulky plow and three horses; with a two-bottom 14 inch gang plow and four horses; and with a gas engine tractor having a four-bottom 14 in. gang plow?

(3) What are the difficulties commonly encountered in inoculating land with prepared cultures of bacteria?

(4) What are the important weed seeds in your community that cannot be eliminated from seed grain by a fanning mill? How would you eliminate such seeds?

(5) What are the best methods to follow in the selection of seed corn ears? Best method of storing seed corn ears to preserve vitality?

(6) Prepare a germination seed box and conduct a germination test for individual ears of corn.

(7) Will the formaldehyde treatment for seed flax and seed potatoes prevent crop injury from flax wilt or potato scab in case these diseases existed on the land the previous year?

(8) How would you eliminate the open smut of barley?

(9) Perform the formaldehyde treatment for seed wheat or other seed grain, and for seed potatoes.

(10) Can potato blight be destroyed after it has made its appearance on the crop?

(11) How long will wild mustard, wild oats, and corn cockle seeds maintain their vitality when buried in the soil?

APPENDIX

COMPENDIUM OF FACTS AND STATISTICS

RULES FOR MEASURING HAY IN MOWS AND STACKS; GRAIN AND ROOTS IN BIN; CORN IN CRIB; AND THE ACREAGE OF FIELDS

Tons of Hay in Mows. Compute the number of cubic feet in the mow by multiplying length by width by depth. Divide the total number of cubic feet in the mow by the number of cubic feet in one ton of hay, which is usually about 400 for well settled timothy or prairie hay, and the quotient so obtained will be the number of tons. The number of cubic feet in one ton of hay varies greatly with the kind of hay, the length of time it has settled, and the size and depth of the hay mass. Timothy and prairie hay pack closer than alfalfa or red clover and, therefore, a smaller number of cubic feet per ton should be used. In the accompanying table a few estimates are shown relative to the number of cubic feet required to make a ton of hay.

Depth of Mow or Height of Stack	Length of Time Standing	Cubic Feet Required
10 ft. to 12 ft.	30 days	613
10 ft. to 12 ft.	60 days	512
12 ft. to 15 ft.	30 days	512
12 ft. to 15 ft.	60 days	422
15 ft. to 18 ft.	30 days	422
18 ft. to 20 ft.	60 days or more	343

From Farm Management by Andrew Boss.

Tons of Hay in Stacks. The number of cubic feet in a hay stack equals .31 multiplied by the overthrow (distance from the ground on one side over the top of the stack to the ground on the other side) by the width by the length. Divide the total number of cubic feet in the stack by the number of cubic feet in one ton, and the quotient will be the number of tons in the stack. As hay stacks are not commonly over 12 feet in depth, an average rule for the number of cubic feet in one ton of stacked hay is: 600 cubic feet for hay standing 30 days, and 500 cubic feet for hay standing 60 days or more.

Bushels of Grain in Bins. Compute the number of cubic feet in the bin by multiplying length by width by depth. Divide this sum by 1.244 (number of cubic feet in one bushel) and the quotient will be the approximate number of bushels in the bin. For more accurate figuring, the number of cubic feet in the bin may be reduced to cubic inches by multiplying by 1728 (cubic inches in 1 cubic foot) and the sum so obtained divided by 215J.42 (cubic inches in one bushel).

Bushels of Potatoes or Other Roots in Bins. Use same method as for grain in bins.

Bushels of Corn in the Crib. Compute the number of cubic feet in the crib by multiplying length by width by depth in case of a square angled bin or crib. Most corn cribs are made wider at the top than at the bottom. In such cribs average the width of the crib at the top of the corn mass with the width at the bottom of the crib and multiply by length and depth to obtain cubic contents. Divide the number of cubic feet in the crib by 2.5 (the approximate number of cubic feet of ear corn to give one bushel of shelled grain), and the quotient so obtained will be the approximate number of bushels of shelled corn in the crib.

Bushels of Grain or Ear Corn in Wagon Boxes. A common farm wagon is usually 10 feet long and 3 feet wide and

will hold approximately two bushels of grain for every inch in depth. Corn on the cob is calculated at the rate of one inch in depth to a bushel of shelled grain.

If the wagon box is 11 feet long and 3 feet wide, there are about 2.2 bu. of grain for every inch in depth, and about 1.1 bu. of shelled corn for every inch of ear corn.

Acreage of Fields. Field acreages may be computed in either rods or feet. One mile is 320 rods or 5,280 feet. One acre contains 160 square rods or 43,560 square feet. Measurement by feet has become more common than measurement by rods. No matter how crooked a field may be, the exact acreage may be easily determined, if measurements are so taken as to plat the field into one or more of the geometric figures that are the common basis for computing acreage, namely, the rectangle, triangle or trapezoid.

The rectangle has four sides with opposite sides parallel, and the number of square feet or rods that it contains is easily determined by multiplying length by width. The triangle is three sided with no sides parallel, and its area is determined by multiplying one half the length of the base by the altitude. In surveying a triangular field to get the proper measurements for computing the area, measure the length of any side and then run a perpendicular line from this side to the opposite apex of the triangle. This perpendicular line is called the altitude and the side of the triangle from which the perpendicular line was projected is called the base. The trapezoid is four sided, with two sides parallel and two sides not parallel. Its area is computed by multiplying one half the sum of the length of the parallel sides by the length of the altitude (a perpendicular line projected from one parallel side to the other). Acreage is determined by dividing the number of square rods or square feet in the field by the number of square rods or square feet in one acre.

LEGAL WEIGHTS OF AGRICULTURAL PRODUCTS

*Legal Weights of Agricultural Products (Pounds per Bushel)

	Barley	Beans	Beets	Blue Grass Seed	Brome Grass Seed	Buckwheat	Clover Seed	Corn (shelled)	Cotton Seed	Flax Seed	Hemp Seed	Millet	Oats	Onions	Peanuts	Peas	Potatoes (Irish)	Potatoes (sweet)	Redtop	Rice (rough)	Rye	Sorghum Seed	Timothy Seed	Turnips	Wheat
Alabama	47	60	...	...	...	...	...	56	32	...	...	...	32	...	...	60	...	55	...	...	56	...	...	55	60
Arizona	45	55	...	...	...	...	...	...	...	...	...	...	32	...	...	...	...	...	...	...	56	...	...	...	60
Arkansas	48	60	...	14	...	52	60	56	33⅓	56	...	50	32	57	...	60	60	50	14	...	56	50	60	57	60
California	50	...	...	...	...	40	...	52	...	...	...	...	32	...	...	...	...	...	...	...	54	...	...	...	60
Colorado	48	60	...	14	...	52	60	56	...	...	44	...	32	57	...	...	60	...	...	...	56	...	45	...	60
Connecticut	48	60	60	...	...	48	60	56	...	55	...	...	32	52	...	60	60	54	...	45	56	...	...	50	60
Delaware	...	...	...	...	...	...	...	56	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	60
Florida	48	60	...	...	...	...	...	56	32	...	...	50	32	56	22	...	60	60	...	...	56	56	...	54	60
Georgia	47	60	...	14	...	52	60	56	30	56	44	...	32	57	...	60	60	55	...	43	56	...	45	55	60
Idaho	48	...	...	...	...	42	60	56	...	56	...	...	36	...	...	...	60	...	...	...	56	...	...	...	60
Illinois	48	60	...	14	...	52	60	56	...	56	44	...	32	57	...	...	60	50	...	...	56	...	45	55	60
Indiana	48	60	...	14	...	50	60	56	...	...	44	50	32	48	...	...	60	55	...	...	56	...	45	55	60
Iowa	48	60	...	14	...	52	60	56	...	56	44	50	32	57	...	...	60	46	...	...	56	30	45	...	60
Kansas	48	60	...	14	...	50	60	56	...	56	44	50	32	57	...	...	60	50	...	...	56	56	45	55	60
Kentucky	47	60	...	14	...	56	60	56	...	56	44	50	32	57	...	60	60	55	...	...	56	...	45	60	60
Louisiana	48	...	...	...	...	...	...	56	...	...	...	...	...	...	...	...	...	...	...	...	56	...	...	...	60
Maine	48	60	60	...	...	48	...	56	...	...	...	...	32	52	...	60	60	...	...	...	50	...	...	50	60
Maryland	...	...	...	...	...	...	...	...	...	...	...	...	26	...	...	...	56	...	...	...	...	...	...	...	...
Massachusetts	48	60	...	...	...	48	60	56	...	55	...	...	32	52	...	60	60	54	...	45	56	...	45	...	60
Michigan	48	60	...	14	...	48	60	56	...	56	44	48	32	52	...	60	60	56	14	...	56	...	45	58	60
Minnesota	48	60	50	14	14	50	60	56	...	...	50	48	32	52	...	60	60	55	14	...	56	57	45	...	60
Mississippi	48	60	...	14	...	48	60	56	32	56	44	50	32	57	...	60	60	60	...	...	56	42	45	55	60
Missouri	48	60	...	14	...	52	60	56	33	56	44	50	32	57	...	60	60	56	14	...	56	42	45	42	60
Montana	48	60	50	14	...	52	60	56	...	56	44	...	32	57	...	60	60	...	...	...	56	...	45	50	60
Nebraska	48	60	...	14	...	52	60	56	...	56	44	50	32	57	...	60	60	50	...	...	56	30	45	55	60
Nevada	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
New Hampshire	...	62	...	...	...	...	...	56	...	...	...	...	32	...	...	60	60	...	...	...	56	...	...	...	60
New Jersey	48	60	...	...	...	50	64	56	...	55	...	...	30	57	...	60	60	54	...	...	56	...	...	...	60
New Mexico	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

*Legal Weights of Agricultural Products (Pounds per Bushel) Continued

	Barley	Beans	Beets	Blue Grass Seed	Brome Grass Seed	Buckwheat	Clover Seed	Corn (shelled)	Cotton Seed	Flax Seed	Hemp Seed	Millet	Oats	Onions	Peanuts	Peas	Potatoes (Irish)	Potatoes (sweet)	Redtop	Rice (rough)	Rye	Sorghum Seed	Timothy Seed	Turnips	Wheat
New York	48	60	...	...	...	48	60	56	...	55	...	...	32	57	...	60	60	54	...	45	56	...	45	...	60
North Carolina	48	...	...	...	...	50	60	56	30	55	...	...	32	...	22	60	...	...	...	44	56	...	...	...	60
North Dakota	48	60	60	...	...	42	60	56	...	56	...	50	32	52	...	60	60	46	...	...	56	...	45	60	60
Ohio	48	60	56	...	...	50	60	56	...	56	44	50	32	55	...	60	60	50	...	...	56	...	45	60	60
Oklahoma	48	60	60	...	...	42	60	56	...	56	...	...	32	52	...	60	60	46	...	...	56	...	42	60	60
Oregon	46	...	...	...	...	42	60	56	...	...	...	...	32	...	...	...	60	...	...	...	56	...	...	...	60
Pennsylvania	47	...	...	...	...	48	60	56	...	...	...	...	32	50	...	...	56	...	...	...	56	...	...	...	60
Rhode Island	48	60	50	...	...	48	60	56	...	56	44	50	32	50	...	60	60	54	...	...	56	...	45	50	60
South Carolina	...	...	...	...	...	...	...	...	30	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
South Dakota	48	60	60	...	...	42	60	56	...	56	...	...	32	52	...	60	60	46	...	...	56	...	42	60	60
Tennessee	48	60	50	14	...	50	60	56	28	56	44	50	32	56	23	60	60	50	...	...	56	50	45	50	60
Texas	48	60	...	...	...	42	60	56	32	56	44	50	32	57	...	...	60	55	...	...	56	...	45	55	60
Utah	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Vermont	48	62	60	...	...	48	60	56	...	...	...	...	32	52	...	60	60	...	...	...	56	...	45	60	60
Virginia	48	60	...	14	...	52	60	56	32	56	44	50	30	57	22	60	56	56	...	...	56	...	45	55	60
Washington	48	...	...	...	...	42	60	56	...	56	...	...	32	...	...	...	60	...	...	...	56	...	...	...	60
West Virginia	48	60	...	...	...	52	60	56	...	56	...	...	32	...	...	...	60	...	...	...	56	...	45	...	60
Wisconsin	48	60	50	...	...	50	60	56	...	56	44	50	32	57	...	60	60	54	...	...	56	...	45	42	60
Wyoming	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

* From Cyclopedia of American Agriculture. Bailey Vol. II.

AMOUNTS OF SEED PER ACRE. DEPTH TO PLANT. METHODS OF PLANTING. CROPS ANNUAL, BIENNIAL OR PERENNIAL

Crops	Annual Biennial Perennial	Amount of Seed per Acre	Depth to Plant	Best Method of Planting
Alfalfa (broadcast)	P	10–15 lbs.	Harrow in	Shotgun seeder or wheelbarrow seeder
Alfalfa (drilled)	P	8–10 lbs.	1–2 in.	Grass seeding attachment on grain drill
Barley (humid climate)	A	2–2½ bu.	2 in.	Grain drill
Barley (semi-arid climate)	A	1½ bu.	3 in.	Grain drill
Bean, field (small seed)	A	2–3 pks.	3 in.	Grain drill in rows 28″, 30″, 35″, 36″ apart
Bean, field (large seed)	A	5–6 pks.	3 in.	Grain drill in rows 28″, 30″, 35″, 36″ apart
Bean, broad (seed)	A	40–50 lbs.	3 in	Grain drill in rows 28″, 30″, 35″, 36″ apart
Bean, broad (forage or silage)	A	60–70 lbs.	3 in	Grain drill in rows 21″, 24″ apart
Bean, velvet	A	½–1 pk.	3 in.	Bean planter, garden drill, or by hand in furrows; rows 42″–48″ apart; 2′ – 3′ in rows
Beets, sugar	B	12–16 lbs.	1–1½ in.	Beet planter, garden drill, or corn planter with sorghum plates
Beets, stock	B	8–12 lbs.	1–1½ in.	Beet planter, garden drill, or corn planter with sorghum plates
Blue grass (alone)	P	15–20 lbs.	1–1½ in.	Shotgun seeder or wheelbarrow seeder
Blue grass (mixtures)	P	4–8 lbs.	1–1½ in.	Shotgun seeder, wheelbarrow seeder, or grass seeding attachment on grain drill
Brome grass (alone)	P	6–8 lbs.	1–1½ in	Brome grass seeder, with grain seed in drill, hand sow and harrow in
Brome grass (mixtures)	P	4–6 lbs.	1–1½ in.	Brome grass seeder, with grain seed in drill, hand sow and harrow in

Amounts of Seed per Acre. Depth to Plant. Methods of Planting. Crops Annual, Biennial or Perennial—Continued.

Crops	Annual Biennial Perennial	Amount of Seed per Acre	Depth to Plant	Best Method of Planting
Broom-corn	A	2 quarts	1½–2 in.	Corn planter with sorghum plates or grain drill, rows 36–42 in. apart
Buckwheat	A	3 pks–1 bu.	1½–2 in.	Grain drill
Clover, alsike (alone)	P	4–5 lbs	1–1½ in.	Grass seeding attachment on grain drill
Clover, alsike (mixtures)	P	2–3 lbs.	1–1½ in.	Grass seeding attachment on grain drill
Clover, crimson	A	4–6 lbs.	1–1½ in.	Grass seeding attachment on grain drill
Clover, mammoth	P	4–6 lbs.	1 1½ in.	Grass seeding attachment on grain drill
Clover, red (alone)	B	4–6 lbs.	1–1½ in.	Grass seeding attachment on grain drill
Clover, red (mixtures)	B	3–5 lbs.	1–1½ in.	Grass seeding attachment on grain drill
Clover, sweet	B	10–15 lbs.	1–2 in.	Grass seeding attachment on grain drill
Clover, white (mixtures)	P	2–3 lbs.	1–1½ in.	Grass seeding attachment on grain drill
Corn, grain	A	7–9 lbs.	1½–2½in.	Check row corn planter
Corn, fodder-ensilage	A	½–1 bu.	1½–2½in.	Corn planter or grain drill
Cotton	A	1–1½ bu.	2–3 in.	Cotton planter
Cowpeas, seed crop	A	2–3 pks.	3 in.	Grain drill in rows 35″–36″ apart
Cowpeas, forage or green manure	A	4–5 pks.	3 in.	Grain drill in rows 12″–14″ apart
Emmer or Speltz	A	2–3 bu.	2–3 in.	Grain drill
Flax, seed crop	A	15–30 lbs.	1½–2 in.	Grain drill
Flax, fiber crop	A	1–1½ bu.	1½–2 in.	Grain drill
Hemp	A	1 bu.	2 in.	Grain drill
Japan Clover (see Lespedeza)				
Kafir corn, seed crop	A	3 6 lbs.	1–1½ in.	Corn planter with sorghum plates, or grain drill, rows 35″, 36″ or 42″ apart
Kafir corn, forage crop	A	1–1½ bu.	1–1½ in.	Grain drill in rows 28″, 30″, 35″ or 36″ apart.

Amounts of Seed per Acre. Depth to Plant. Methods of Planting. Crops Annual, Biennial or Perennial—Continued.

Crops	Annual Biennial Perennial	Amount of Seed per Acre	Depth to Plant	Best Method of Planting
Lespedeza	A	10–15 lbs.	1-1½ in.	Shotgun seeder, wheelbarrow seeder, or grass seeding attachment on grain drill
Lupine	A	80–100 lbs.	2 in.	Grain drill in rows 12″ to 14″ apart
Mangel-wurzel	B	5–8 lbs.	1-1½ in	Beet planter, garden drill, or corn planter with sorghum plates
Millet, barnyard	A	1 2 pks.	1-1½ in.	Grain drill. For hay crop sow same as cereals with all tubes open. For seed crop of hog, Proso and Japan millets sow in cultivable rows 28″ to 36″ apart
Millet, German	A	1–2 pks.	1-1½ in.	
Millet, hog	A	2–3 pks.	1-1½ in.	
Millet, Japanese	A	2-3 pks.	1-1½ in.	
Millet, Proso	A	2–3 pks.	1 1½ in	
Milo maize	A	(Same as K	afir corn)	
Oats, (humid climate)	A	2½–3 bu.	2–3 in.	Grain drill
Oats, (semi-arid climate)	A	1½–2 bu	2–3 in.	Grain drill
Orchard grass	P	8–12 lbs.	1-1½ in.	Wheelbarrow seeder or with grain in the grain drill
Peanut	A	....	2 in	Hand sow or with planter in cultivable rows, plants 8″ to 12″ apart
Peas, Canadian field (alone)	A	2 bu.	2–3 in.	Grain drill
Peas, Canadian field with oats	A	2 bu. oats 1 bu. peas	2–3 in	Grain drill
Peas, wrinkled (seed)	A	3 bu.	3–4 in.	Grain drill
Pop-corn	A	3 lbs.	1-1½ in.	Garden drill or corn planter
Potato, Irish	A	8 15 bu.	3–4 in.	1 or 2 row planter
Potato, sweet	A	(Plants set	in field fr	om hotbeds
Rape, broadcast alone	A	3–4 lbs.	Harrow in	Shotgun seeder or wheelbarrow seeder
Rape, catch crop	A	2–3 lbs.	1-1½ in.	With seed grain in grain drill or with shotgun seeder in corn last cultivation
Redtop, alone	P	4–6 lbs.	1-1½ in	Wheelbarrow seeder or grass seeding attachment on grain drill
Redtop, mixtures	P	2–6 lbs.	1-1½ in.	Wheelbarrow seeder or grass seeding attachment on grain drill

Amounts of Seed per Acre. Depth to Plant. Methods of Planting. Crops Annual, Biennial or Perennial—Continued.

Crops	Annual Biennial Perennial	Amount of Seed per Acre	Depth to Plant	Best method of Planting
Rice	A	1–1¼ bu.	2 in.	Grain drill
Rutabaga	B	3–5 lbs.	1 in.	Broadcast with shotgun seeder, wheelbarrow seeder, or drill with garden drill
Rye, (humid climate)	A	1¼–1½ bu.	2–3 in.	Grain drill
Rye, (semi-arid climate)	A	1 bu.	2–3 in.	Grain drill
Rye grass	P	2 bu.	1–1½ in.	Hand sow
Sainfoin	P	40–60 lbs. of hulled seed.	3–4 in.	Grain drill
Sorghum, (seed crop)	A	3–5 lbs.	2 in.	Corn planter with sorghum plates
Sorghum, (fodder crop)	A	3–5 pks.	2 in.	Corn planter with sorghum plates or grain drill in 24″–36″ rows
Soy bean, (seed crop)	A	½ bu.	3 in	Bean planter, corn planter or grain drill in cultivable rows 30″ to 36″ apart
Soy bean (forage or green manure)	A	3 pks.	3 in.	Grain drill in 12″ to 14″ rows
Speltz (see Emmer)	....	....	....	....
Sudan grass (humid climate)	A	16–24 lbs.	1–1½ in.	Grain drill
Sudan grass (semi-arid climate)	A	4–6 lbs.	1½–2 in.	Grain drill in cultivable rows 28″ 30″ 35″ or 36″ apart.
Sugar cane	P	4 T. cane	3–6 in.	Cuttings set in furrows 4′–6′ apart and covered with a plow
Sunflower	A	8–10 lbs.	1½ in.	Corn planter or grain drill 36″ to 42″ rows
Timothy, (alone)	P	10–15 lbs.	1–1½ in.	Grass seeding attachment on grain drill
Timothy (mixtures)	P	5–8 lbs.	1–1½ in.	Grass seeding attachment on grain drill
Tobacco	A	(1 tablespo	onful see	d to 100 sq. yards of seed bed will plant 6 acres)
Turnip (drills)	B	1 lb.	1 in.	Garden drill
Vetch, hairy	A	2–4 pks.	1–2 in.	Grain drill
Vetch, kidney	P	2–4 pks.	1–2 in.	Grain drill
Vetch, Dakota	A	2–4 pks.	1–2 in.	Grain drill
Wheat, (humid climate)	A	1¼–1½ bu.	2 in.	Grain drill
Wheat, (semi-arid climate)	A	50–60 lbs.	3 in.	Grain drill
Wheat, durum (humid)	A	1½ bu.	2 in.	Grain drill
Wheat, durum (semi-arid)	A	1 bu.	3 in.	Grain drill

STANDARD GRASS MIXTURES

(1) Rotation Meadows and Pastures.

1. Timothy 8 lbs.
   Red clover 5 lbs.
2. Timothy 8 lbs.
   Alsike clover 3 lbs.
3. Brome grass 6 lbs.
   Alsike clover 3 lbs.
4. Timothy 6 lbs.
   Red-top 4 lbs. clean seed.
   Red clover 4 lbs.

(2) Permanent Meadows or Pastures (High, Well Drained Land).

1. Timothy 8 lbs.
   Alsike clover 3 lbs.
2. Brome grass 6 lbs.
   Timothy 4 lbs.
   Alsike clover 3 lbs.
3. Timothy 6 lbs.
   Redtop 4 lbs. clean seed
   Alsike clover 3 lbs.
4. Kentucky Blue grass 6 lbs.
   White clover 1 lb.
   Timothy 6 lbs.
   Alsike clover 2 lbs.

(3) Permanent Meadows or Pastures (Lowland).

1. Timothy 4 lbs.
   Redtop 4 lbs. clean seed
   Alsike 3 lbs.
2. Brome grass 6 lbs.
   Timothy 4 lbs.
   Alsike clover 3 lbs.
3. Perennial rye grass 10 lbs.
   Alsike clover 3 lbs.

COMPOSITION AND AMOUNTS OF MANURE PRODUCED BY DIFFERENT KINDS OF FARM ANIMALS.

Kind of Animal and Kinds of Food Fed	Analysis				Amount per 1,000 Lbs. Live Weight			
	Per cent Water	Per cent Nitrogen	Per cent Phosphorus	Per cent Potassium	Lbs. per Day	Lbs. per Year	Lbs. Absorbents per Year	Total Tons Farm Manure per Year
Sheep. Fed hay, corn, oats; or hay, wheat bran, cotton seed meal and linseed meal........	59.52	.77	4.10	.59	34.1	12,446	5,000	8.7
Swine. Fed skim milk, corn meal, meat scraps; or corn meal, wheat bran and linseed meal......................	74.13	.84	.17	.32	83.6	30,514	5,000	17.7
Cattle. Fed hay, silage, beets, wheat bran, corn meal, and cottonseed meal.............	75.25	.43	.127	.44	74.1	27,046	3,000	15.0
Horses. Fed hay, oats, corn meal and wheat bran........	48.69	.49	.114	.48	48.8	17,812	3,300	10.5

NOTE: The analyses and amounts of manure produced by farm animals, as shown in this table, are from the Cornell Experiment Station, and the estimates of pounds absorbents per year from "Farm Management" by Andrew Boss. It is estimated that under average farm conditions 50% of the elements of fertility in farm manures is lost by leaching and fermentation. Direct hauling of manure to the field, or composting in concrete pits, will prevent much of this loss.

AMOUNTS OF NITROGEN, PHOSPHORUS, AND POTASSIUM IN ANIMAL PRODUCTS.

Animal Products	Amount	Pounds		
		Nitrogen	Phosphorus	Potassium
Fat cattle...........	1,000 lbs.	25	7	1
Fat hogs............	1,000 lbs.	18	3	1
Milk................	10,000 lbs.	57	7	12
Butter..............	500 lbs.	1	0.2	0.1

From Bulletin 123, Illinois Agricultural Experiment Station.

ANNUAL MAINTENANCE COSTS FOR DAIRY CATTLE.

(From Bulletin 88, Bureau of Statistics, U. S. Dept. of Agriculture.)

Average Annual Food Consumption per Cow.

Year	S.E. Minn				S.W. Minn.				N.W. Minn.			
	Roughage	Farm Grain	Mill Feed	Pasture	Roughage	Farm Grain	Mill Feed	Pasture	Roughage	Farm Grain	Mill Feed	Pasture
	Lbs.	*Lbs.*	*Lbs.*	*Days*	*Lbs.*	*Lbs.*	*Lbs.*	*Days*	*Lbs.*	*Lbs.*	*Lbs.*	*Days*
1904......	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	5,290	635	15	168
1905......	6,014	584	306	174	(1)	(1)	(1)	(1)	5,923	570	4	153
1906......	5,272	418	308	173	3,409	1,045	33	178	6,005	906	55	124
1907......	4,766	609	239	157	4,513	1,100	161	154	4,666	678	128	151
1908......	5,554	421	420	170	3,939	631	250	182	6,501	706	59	162
1909......	6,345	656	357	160	4,250	379	391	171	4,800	834	15	157
Average:												
1904–1909	.....	.....	.....	.....	.....	.....	.....	.....	5,531	722	46	153
1905–1909	5,590	538	326	167	.....	.....	.....	.....	.....	.....	.....	.....
1906–1909	.....	.....	.....	.....	4,028	789	209	171	.....	.....	.....	.....

[1] No data.

Annual Cost of Maintenance of a Cow

(S. E. MINNESOTA)

	1905	1906	1907	1908	1909	Average 1905–09
	Dollars	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
Cash Sundries..................	.78	.55	.74	1.03	.71	.75
Cash Feed.....................	2.89	2.31	3 04	5.37	5.18	3.65
Farm Feed.....................	22.77	23.79	24.12	27.00	21.72	23.85
Labor..........................	16.99	17.26	16.47	22.88	20.56	18.66
General Expense...............	3 15	2.04	1.43	3.47	2.67	2.53
Shelter........................	2.46	2.46	2.46	2.46	2.46	2.46
Depreciation..................	1.68	1.97	1.82	4.50	6.74	3.19
Machinery and Equipment....	.28	.26	.61	.99	.90	.58
Herd Bulls.....................	1.65	1.84	2.13	2.12	2.26	1.98
Interest on Investment	1.77	1.92	2 02	2 53	3.62	2.35
Total..................	54 42	54.40	54 84	72.35	66 82	60.00

(S. W. MINNESOTA)

	1906	1907	1908	1909	Average 1906–09
	Dollars	*Dollars*	*Dollars*	*Dollars*	*Dollars*
Cash Sundries	.38	.17	.46	.18	.28
Cash Feed	.16	1.67	2.46	3.64	1.49
Farm Feed	18.69	22.43	20.17	18.30	20.33
Labor	13.64	17.01	12.74	14.66	15.01
General Expense	1.53	2.21	1.31	3.05	1.97
Shelter	2.46	2.46	2.46	2.46	2.46
Depreciation	.36	.35	.34	.40	.36
Machinery and Equipment	.23	.66	.98	1.97	.71
Herd Bulls	1.42	2.93	1.61	1.69	2.08
Interest on Investment	1.59	1.46	1.46	1.52	1.51
Total	40.46	51.35	43.99	47.87	46.20

(N. W. MINNESOTA)

	1904	1905	1906	1907	1908	1909	Average 1904–09
	Dollars	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
Cash Sundries	.13	.15	.49	.65	.39	.34	.39
Cash Feed	.11	.23	.40	1.05	.70	.16	.48
Farm Feed	16.97	15.74	17.73	18.15	23.06	24.51	19.60
Labor	16.09	15.60	17.73	18.64	19.04	20.83	18.20
General Expense	2.42	2.36	2.72	1.69	2.76	4.48	2.75
Shelter	2.46	2.46	2.46	2.46	2.46	2.46	2.46
Depreciation	.30	.28	.31	.29	.29	.32	.30
Machinery and Equipment	.31	1.46	.76	.96	.81	1.32	.92
Herd Bulls	1.84	2.90	2.19	2.07	2.79	2.88	2.42
Interest on Investment	1.57	1.41	1.55	1.46	1.46	1.61	1.51
Total	42.20	42.59	46.34	47.42	53.76	58.91	49.03

Percentage of Items of Cost of Maintenance to Total Maintenance.

Item	S.E. Minn. Average 5 years	S.W. Minn. Average 4 years	N.W. Minn. Average 6 years
	Per Cent.	*Per Cent.*	*Per Cent.*
Cash sundries	1.2	0.6	0.8
Cash feed	6.1	3.2	1.0
Farm feed	39.7	44.0	39.9
Labor	31.1	32.5	37.1
General expense	4.2	4.3	5.6
Shelter	4.1	5.4	5.0
Depreciation	5.3	.8	.6
Machinery and equipment	1.0	1.5	1.9
Herd bulls, maintenance of	3.3	4.5	4.9
Interest on investment	4.0	3.2	3.2
	100.0	100.0	100.0

QUANTITY OF MILK REQUIRED TO COVER COSTS OF MAINTENANCE OF COWS OF DIFFERENT VALUE.

(From Bulletin 88, Bureau of Statistics, U. S. Dept. of Agriculture.)

Value of Cow	Cost of Maintenance per Year			Milk at $1 20 per 100 Pounds Required to Cover Cost per Year
	Interest and Depreciation	All Other Costs	Total	
Dollars	*Dollars*	*Dollars*	*Dollars*	*Pounds*
40.00	4.36	54.45	58.81	4,901
50.00	6.22	54.45	60.67	5,056
60.00	8.10	54.45	62.55	5,212
70.00	9.96	54.45	64.41	5,368
80.00	11.84	54.45	66.29	5,524
90.00	13.70	54.45	68.15	5,679
100.00	15.58	54.45	70.03	5,836
110.00	17.44	54.45	71.89	5,991
120.00	19.32	54.45	73.77	6,148
130.00	21.18	54.45	75.63	6,302
140.00	23.06	54.45	77.51	6,459
150.00	24.92	54.45	79.37	6,614

HAECKER FEEDING STANDARDS AND METHODS FOR FORMULATING RATIONS FOR DAIRY COWS.

(From Bulletin 130. Minnesota Agricultural Experiment Station.)

Table I. Food of Maintenance.

Weight	Pro.	C-H.	Fat	Weight	Pro.	C-H.	Fat
800	.560	5.60	.08	1225	.857	8.57	.12
825	.577	5.77	.08	1250	.875	8.75	.12
850	.595	5.95	.08	1275	.892	8.92	.13
875	.612	6.12	.09	1300	.910	9.10	.13
900	.630	6.30	.09	1325	.927	9.27	.13
925	.647	6.47	.09	1350	.945	9.45	.13
950	.665	6.65	.09	1375	.962	9.62	.14
975	.682	6.82	.10	1400	.980	9.80	.14
1000	.700	7.00	.10	1425	.997	9.97	.14
1025	.717	7.17	.10	1450	1.015	10.15	.14
1050	.735	7.35	.10	1475	1.032	10.32	.15
1075	.752	7.52	.11	1500	1.050	10.50	.15
1100	.770	7.70	.11	1525	1.067	10.67	.15
1125	.787	7.87	.11	1550	1.085	10.85	.15
1150	.805	8.05	.11	1575	1.102	11.02	.16
1175	.822	8.22	.12	1600	1.120	11.20	.16
1200	.840	8.40	.12	1625	1.137	11.36	.16

Table II. Net Nutrients Required for the Production of Milk Containing a Given Per Cent of Butter-fat.

Lbs. of Milk	% FAT IN MILK 3.0			% FAT IN MILK 3.2			% FAT IN MILK 3.4		
	Pro.	C-H.	Fat	Pro.	C-H.	Fat	Pro.	C-H.	Fat
1	.047	.20	.017	.048	.21	.018	.049	.22	.018
2	.094	.40	.034	.096	.41	.036	.097	.43	.037
3	.141	.60	.051	.143	.62	.053	.146	.65	.055
4	.188	.80	.068	.191	.83	.071	.194	.87	.074
5	.234	.99	.085	.239	1.04	.089	.243	1.08	.092
6	.281	1.19	.102	.287	1.24	.107	.292	1.30	.111
7	.328	1.39	.119	.335	1.45	.125	.340	1.51	.129
8	.375	1.59	.136	.382	1.66	.142	.389	1.73	.148
9	.422	1.79	.153	.430	1.87	.160	.437	1.95	.166
10	.469	1.99	.170	.478	2.07	.178	.486	2.16	.185

Table II. Net Nutrients Required for the Production of Milk Containing a Given Per Cent of Butter-fat.

Lbs. of Milk	% FAT IN MILK 3.6			% FAT IN MILK 3.8			% FAT IN MILK 4.0		
	Pro.	C-H.	Fat	Pro.	C-H	Fat	Pro.	C-H.	Fat
1	.050	.22	.019	.052	.23	.020	.054	.24	.021
2	.100	.45	.039	.104	.47	.040	.108	.48	.042
3	.150	.68	.058	.156	.70	.060	.162	.73	.062
4	.200	.90	.077	.208	.93	.080	.216	.97	.083
5	.250	1.13	.096	.260	1.17	.100	.269	1.21	.104
6	.301	1.35	.116	.312	1.40	.120	.323	1.45	.125
7	.351	1.58	.135	.364	1.64	.140	.377	1.70	.146
8	.401	1.80	.154	.416	1.87	.160	.431	1.94	.166
9	.451	2.03	.174	.468	2 10	.180	.485	2.18	.187
10	.501	2.25	.193	.520	2.34	.200	.539	2.42	.208
	4.2			**4.4**			**4.6**		
1	.055	.25	.021	.056	.26	.022	.058	.27	.023
2	.111	.50	.043	.113	.52	.044	.116	.54	.046
3	.166	.75	.064	.169	.78	.067	.174	.80	.069
4	.221	1.00	.086	.226	1.04	.089	.232	1.07	.092
5	.276	1.25	.107	.282	1.30	.111	.289	1.34	.115
6	.332	1 50	.129	.339	1.56	.133	.347	1.61	.138
7	.387	1.76	.150	.395	1.82	.155	.405	1.88	.161
8	.442	2.01	.172	.452	2.08	.178	.463	2.14	.184
9	.497	2.26	.193	.508	2.34	.200	.521	2.41	.207
10	.553	2.51	.215	.565	2.60	.222	.579	2.68	.230
	4.8			**5.0**			**5.2**		
1	.059	.28	.024	.060	.28	.024	.062	.29	.025
2	.118	.55	.047	.121	.57	.049	.124	.58	.050
3	.177	.83	.071	.181	.85	.073	.185	.87	.075
4	.236	1.11	.094	.242	1.14	.097	.247	1.17	.100
5	.295	1.38	.118	.302	1.42	.121	.309	1.46	.125
6	.355	1.66	.142	.362	1.70	.146	.371	1.75	.150
7	.414	1.93	.165	.423	1.99	.170	.433	2.04	.175
8	.473	2.21	.189	.483	2.27	.194	.494	2.33	.200
9	.532	2.49	.212	.544	2.56	.219	.556	2.62	.225
10	.591	2.76	.236	.604	2.84	.243	.618	2.91	.250

Table II. Net Nutrients Required for the Production of Milk Containing a Given Per Cent of Butter-fat.

Lbs. of Milk	% FAT IN MILK 5.4			% FAT IN MILK 5.6			% FAT IN MILK 5.8		
	Pro.	C-H.	Fat	Pro.	C-H.	Fat	Pro.	C-H.	Fat
1	.063	.30	.026	.064	.31	.026	.066	.31	.027
2	.126	.60	.051	.129	.61	.053	.131	.63	.054
3	.190	.90	.077	.193	.92	.079	.197	.94	.081
4	.253	1.20	.102	.258	1.23	.105	.262	1.26	.108
5	.316	1.49	.128	.322	1.53	.131	.328	1.57	.134
6	.379	1.79	.154	.386	1.84	.158	.394	1.89	.161
7	.442	2.09	.179	.451	2.15	.184	.459	2.20	.188
8	.506	2.39	.205	.515	2.45	.210	.525	2.51	.215
9	.569	2.69	.230	.580	2.76	.237	.590	2.83	.242
10	.632	2.99	.256	.644	3.07	.263	.656	3.14	.269
	6.0			6.2			6.4		
1	.067	.32	.028	.069	.33	.028	.071	.34	.029
2	.134	.64	.055	.138	.66	.057	.142	.67	.058
3	.200	.97	.083	.207	.99	.085	.213	1.01	.087
4	.267	1.29	.110	.276	1.32	.113	.284	1.35	.116
5	.334	1.61	.138	.344	1.65	.141	.355	1.69	.144
6	.401	1.93	.166	.413	1.98	.170	.426	2.03	.173
7	.468	2.25	.193	.482	2.31	.198	.497	2.36	.202
8	.534	2.58	.221	.551	2.64	.226	.568	2.70	.231
9	.601	2.90	.248	.620	2.97	.255	.639	3.04	.260
10	.668	3.22	.276	.689	3.30	.283	.710	3.38	.289

Table III. Pounds of Dry Matter and Nutrients Contained in a Given Number of Pounds of Feed Stuff.

CURED ROUGHAGE

Fodder Corn (Drilled)

Lbs.	Dry Matter	Digestible Pro.	Digestible C-H	Digestible Fat
1	.76	.037	.41	.015
2	1.52	.074	.83	.029
3	2.28	.111	1.24	.044
4	3 04	.148	1.66	.058
5	3.80	.185	2.07	.073
6	4 56	.222	2.48	.088
7	5.32	.259	2.90	.102
8	6.08	.296	3.31	.117
9	6.84	.333	3.73	.131
10	7.60	.370	4.14	.146

Corn Stover

Lbs.	Dry Matter	Digestible Pro.	Digestible C-H	Digestible Fat
1	.59	.014	.31	.007
2	1.19	.028	.62	.014
3	1.78	.042	.94	.021
4	2.38	.056	1.25	.028
5	2 97	.070	1.56	.035
6	3.57	.084	1.87	.042
7	4.16	.098	2.18	.049
8	4.76	.112	2.50	.056
9	5.35	.126	2.81	.063
10	5.98	.140	3.12	070

Sorghum Fodder

Lbs.	Dry Matter	Digestible Pro.	Digestible C-H	Digestible Fat
1	.50	.024	.32	.016
2	1.01	.048	.64	.032
3	1.51	.072	.96	.048
4	2 01	.096	1.28	.064
5	2 51	.120	1.60	.080
6	3 02	.144	1.93	.096
7	3.52	.168	2.25	.112
8	4.02	.192	2.57	.128
9	4.53	.216	2.89	.144
10	5.03	.240	3.21	.160

Millet

Lbs.	Dry Matter	Digestible Pro.	Digestible C-H	Digestible Fat
1	.86	.050	.47	.011
2	1.72	.100	.94	.022
3	2.58	.150	1.41	.033
4	3.44	.200	1.88	.044
5	4.30	.250	2.34	.055
6	5.16	.300	2.81	.066
7	6.02	.350	3.28	.077
8	6.88	.400	3.75	.088
9	7.74	.450	4.22	.099
10	8.60	.500	4.69	.110

Timothy

Lbs.	Dry Matter	Digestible Pro.	Digestible C-H	Digestible Fat
1	.87	.028	.43	.014
2	1.74	.056	.87	.028
3	2.60	.084	1.30	.042
4	3.47	.112	1.74	.056
5	4 34	.140	2.17	.070
6	5.21	.168	2.60	.084
7	6.08	.196	3.04	.098
8	6.94	.224	3.47	.112
9	7.81	.252	3.91	.126
10	8.68	.280	4.34	.140

Red Top

Lbs.	Dry Matter	Digestible Pro.	Digestible C-H	Digestible Fat
1	.91	.048	.47	.010
2	1.82	.096	.94	.020
3	2.73	.144	1.41	.030
4	3,64	.192	1.88	.040
5	4 55	.240	2.34	.050
6	5.47	.288	2 81	.060
7	6.38	.336	3.28	.070
8	7.29	.384	3.75	.080
9	8.20	.432	4.22	.090
10	9.11	.480	4.69	.100

Prairie (Upland)

Lbs.	Dry Matter	Digestible Pro.	Digestible C-H	Digestible Fat
1	.87	.03	.42	.014
2	1.75	.06	.84	.028
3	2.62	.09	1.25	.042
4	3 50	.12	1.67	.056
5	4.37	.15	2.09	.070
6	5.25	.18	2.51	.084
7	6.12	.21	2.93	.098
8	7.00	.24	3.34	.112
9	7.87	.27	3.76	.126
10	8.75	.30	4.18	.140

Prairie (Mixed)

Lbs.	Dry Matter	Digestible Pro.	Digestible C-H	Digestible Fat
1	.84	.029	.41	.012
2	1.62	.058	.83	.024
3	2.52	.087	1.24	.036
4	3 36	.116	1.66	.048
5	4.20	.145	2.07	.060
6	5.05	.174	2.49	.072
7	5.89	.203	2.90	.084
8	6.73	.232	3.32	.096
9	7.57	.261	3.73	.108
10	8.41	.290	4.15	.120

Prairie (Swale)

Lbs.	Dry Matter	Digestible Pro.	Digestible C-H	Digestible Fat
1	.86	.026	.42	.011
2	1.73	.052	.84	.022
3	2.59	.078	1.26	.033
4	3 45	.104	1.68	.044
5	4.31	.130	2.09	.055
6	5.18	.156	2.51	.066
7	6.04	.182	2.93	.077
8	6.90	.208	3.35	.088
9	7.77	.234	3.77	.099
10	8.63	.260	4.19	.110

Barley

Lbs.	Dry Matter	Digestible Pro.	Digestible C-H	Digestible Fat
1	.85	.057	.44	.01
2	1.70	.114	.87	.02
3	2.55	.171	1.31	.03
4	3.40	.228	1.74	.04
5	4.25	.285	2.18	.05
6	5.10	.342	2.62	.06
7	5.95	.399	3.05	.07
8	6.80	.456	3.49	.08
9	7.65	.513	3.92	.09
10	8.50	.570	4.36	.10

Oat

Lbs.	Dry Matter	Digestible Pro.	Digestible C-H	Digestible Fat
1	.86	.047	.37	.017
2	1.72	.094	.73	.034
3	2.58	.141	1.10	.051
4	3.44	.188	1.47	.068
5	4.30	.235	1.83	.085
6	5.16	.282	2.20	.102
7	6.02	.329	2.57	.119
8	6.88	.376	2.94	.136
9	7.74	.423	3.30	.153
10	8.60	.470	3.67	.170

Pea

Lbs.	Dry Matter	Digestible Pro.	Digestible C-H	Digestible Fat
1	.90	.080	.41	.017
2	1.80	.160	.82	.034
3	2.71	.240	1.23	.051
4	3.61	.320	1.64	.068
5	4.51	.400	2.05	.085
6	5 41	.480	2.47	.102
7	6.31	.560	2.88	.119
8	7.22	.640	3.29	.136
9	8.12	.720	3.70	.153
10	9.02	.800	4.11	.170

Table III. Pounds of Dry Matter and Nutrients Contained in a Given Number of Pounds of Feed Stuff.

CURED ROUGHAGE

Cow Pea					Soy Bean					White Clover				
Lbs.	Dry Matter	Digestible			Lbs.	Dry Matter	Digestible			Lbs.	Dry Matter	Digestible		
		Pro.	C-H	Fat			Pro.	C-H	Fat			Pro.	C-H	Fat
1	.89	.058	.39	.013	1	.88	.106	.41	.012	1	.90	.115	.42	.015
2	1.79	.116	.78	.026	2	1.76	.212	.82	.024	2	1.81	.230	.84	.030
3	2.68	.174	1.18	.039	3	2.65	.318	1.23	.036	3	2.71	.345	1.27	.045
4	3.58	.232	1.57	.052	4	3.53	.424	1.64	.048	4	3.61	.460	1.69	.060
5	4.47	.290	1.96	.065	5	4.41	.530	2.04	.060	5	4.51	.575	2.11	.075
6	5.37	.348	2.36	.078	6	5.29	.636	2.45	.072	6	5.42	.690	2.53	.090
7	6.26	.406	2.75	.091	7	6.17	.742	2.86	.084	7	6.32	.805	2.95	.105
8	7.16	.464	3.14	.104	8	7.06	.848	3.27	.096	8	7.22	.920	3.38	.120
9	8.05	.522	3.54	.117	7	7.94	.954	3.68	.108	9	8.13	1.035	3 80	.135
10	8.95	.580	3.93	.130	10	8.82	1.060	4.09	.120	10	9.03	1.150	4.22	.150

Red Clover					Alsike Clover					Alfalfa				
1	.85	.071	.38	.018	1	.90	.084	.42	.015	1	.94	.117	.41	.01
2	1.69	.142	.76	.036	2	1.81	.168	.85	.030	2	1.87	.234	.82	.02
3	2.54	.213	1.13	.054	3	2.71	.252	1.27	.045	3	2.81	.351	1.23	.03
4	3.39	.284	1.51	.072	4	3.61	.336	1.70	.060	4	3.74	.467	1.64	.04
5	4.23	.355	1.89	.090	5	4.51	.420	2.12	.075	5	4.68	.585	2.04	.05
6	5.08	.426	2.27	.108	6	5.42	.504	2.55	.090	6	5.62	.702	2.45	.06
7	5.93	.497	2.65	.128	7	6.32	.588	2.97	.105	7	6.55	.819	2.86	.07
8	6.78	.568	3.02	.144	8	7.22	.672	3.40	.120	8	7.49	.936	3.27	.08
9	7.62	.639	3.40	.162	9	8.13	.756	3.82	.135	9	8.42	1.053	3.68	.09
10	8.47	.710	3.78	.180	10	9.03	.840	4.25	.150	10	9.36	1.170	4.09	.10

Wheat Straw					Oat Straw					Barley Straw				
1	.90	.008	.35	.004	1	.91	.013	.39	.008	1	.86	.009	.40	.006
2	1.81	.016	.70	.008	2	1.82	.026	.79	.016	2	1.72	.018	.80	.012
3	2.71	.024	1.06	.012	3	2.72	.039	1.18	.024	3	2.57	.027	1.20	.018
4	3.63	.032	1.41	.016	4	3.63	.052	1.58	.032	4	3.43	.036	1.60	.024
5	4.52	.040	1.76	.020	5	4.54	.065	1.97	.040	5	4.29	.045	2.00	.030
6	5.42	.048	2.11	.024	6	5.45	.078	2.37	.048	6	5.15	.054	2.41	.036
7	6.33	.056	2.46	.028	7	6.36	.091	2.76	.056	7	6.01	.063	2.81	.042
8	7.23	.064	2.82	.032	8	7.26	.104	3.16	.064	8	6.86	.072	3.21	.048
9	8.14	.072	3.17	.036	9	8.17	.117	3.55	.072	9	7.72	.081	3.61	.054
10	9.04	.080	3.52	.040	10	9.08	.130	3.95	.080	10	8.58	.090	4.01	.060

Kafir Forage					Oat and Pea					Oat and Vetch				
1	.48	.009	.26	.011	1	.89	.076	.41	.015	1	.85	.083	.36	.013
2	.96	.019	.52	.022	2	1.79	.152	.83	.030	2	1.70	.166	.72	.026
3	1.44	.028	.78	.033	3	2.68	.228	1.24	.045	3	2.55	.249	1.07	.039
4	1.92	.038	1.04	.044	4	3.58	.304	1.66	.060	4	3.40	.332	1.43	.052
5	2.39	.047	1.29	.055	5	4.47	.380	2.07	.075	5	4 25	.415	1.79	.065
6	2.87	.057	1.55	.066	6	5.37	.456	2.49	.090	6	5.10	.498	2.15	.078
7	3.35	.066	1.81	.077	7	6.26	.532	2.90	.105	7	5.95	.581	2.51	.091
8	3.83	.076	2.07	.088	8	7.16	.608	3.32	.120	8	6.80	.664	2.86	.104
9	4.31	.085	2.33	.099	9	8.05	.684	3.73	.135	9	7.65	.747	3.22	.117
10	4.79	.095	2.59	.110	10	8.95	.760	4.15	.150	10	8.50	.830	3 58	.130

Table III. Pounds of Dry Matter and Nutrients Contained in a Given Number of Pounds of Feed Stuff.

SILAGE

Corn Silage

Lbs.	Dry Matter	Digestible Pro.	Digestible C-H	Digestible Fat
1	.26	.012	.14	.007
2	.53	.025	.28	.014
3	.79	.037	.43	.021
4	1.06	.050	.57	.028
5	1.32	.062	.71	.035
6	1.58	.075	.85	.042
7	1.85	.087	.99	.049
8	2.11	.100	1.14	.056
9	2.38	.112	1.28	.063
10	2.64	.125	1.42	.070

Sorghum Silage

Lbs.	Dry Matter	Digestible Pro.	Digestible C-H	Digestible Fat
1	.24	.001	.13	.002
2	.48	.002	.27	.004
3	.72	.003	.40	.006
4	.96	.004	.54	.008
5	1.19	.005	.67	.010
6	1.43	.006	.81	.012
7	1.67	.007	.94	.014
8	1.91	.008	1.08	.016
9	2.15	.009	1.21	.018
10	2.39	.010	1.35	.020

Clover Silage

Lbs.	Dry Matter	Digestible Pro.	Digestible C-H	Digestible Fat
1	.28	.020	.13	.010
2	.56	.040	.27	.020
3	.84	.060	.40	.030
4	1.12	.080	.54	.040
5	1.40	.100	.67	.050
6	1.68	.120	.81	.060
7	1.96	.140	.94	.070
8	2.24	.160	1.08	.080
9	2.52	.180	1.21	.090
10	2.80	.200	1.35	.100

Alfalfa Silage

Lbs.	Dry Matter	Digestible Pro.	Digestible C-H	Digestible Fat
1	.27	.030	.08	.019
2	.55	.060	.17	.038
3	.82	.090	.25	.057
4	1.10	.120	.34	.076
5	1.37	.150	.42	.095
6	1.65	.180	.51	.114
7	1.92	.210	.59	.133
8	2.20	.240	.68	.152
9	2.47	.270	.76	.171
10	2.75	.300	.85	.190

Cow Pea Silage

Lbs.	Dry Matter	Digestible Pro.	Digestible C-H	Digestible Fat
1	.21	.015	.09	.009
2	.41	.030	.17	.018
3	.62	.045	.26	.027
4	.83	.060	.34	.036
5	1.03	.075	.43	.045
6	1.24	.090	.52	.054
7	1.45	.105	.60	.063
8	1.66	.120	.69	.072
9	1.86	.135	.77	.081
10	2.07	.150	.86	.090

Soy Bean Silage

Lbs.	Dry Matter	Digestible Pro.	Digestible C-H	Digestible Fat
1	.26	.027	.09	.013
2	.52	.054	.17	.026
3	.77	.081	.26	.039
4	1.03	.108	.35	.052
5	1.29	.135	.43	.065
6	1.55	.162	.52	.078
7	1.81	.189	.61	.091
8	2.06	.216	.70	.104
9	2.32	.243	.78	.117
10	2.58	.270	.87	.130

Pea Cannery Refuse

Lbs.	Dry Matter	Digestible Pro.	Digestible C-H	Digestible Fat
1	.23	.021	.13	.008
2	.46	.042	.26	.016
3	.70	.063	.39	.024
4	.93	.084	.52	.032
5	1.16	.105	.65	.040
6	1.39	.126	.79	.048
7	1.62	.147	.92	.056
8	1.86	.168	1.05	.064
9	2.09	.189	1.18	.072
10	2.32	.210	1.31	.080

Corn Cannery Refuse

Lbs.	Dry Matter	Digestible Pro.	Digestible C-H	Digestible Fat
1	.21	.003	.12	.006
2	.42	.006	.24	.012
3	.63	.009	.36	.018
4	.84	.012	.48	.024
5	1.05	.015	.59	.030
6	1.26	.018	.71	.036
7	1.47	.021	.83	.042
8	1.68	.024	.95	.048
9	1.89	.027	1.07	.054
10	2.10	.030	1.19	.060

Table III. Pounds of Dry Matter and Nutrients Contained in a Given Number of Pounds of Feed Stuff.

ROOTS AND TUBERS

Carrot					Potato				
Lbs.	Dry Matter	Digestible Pro.	Digestible C-H	Digestible Fat	Lbs.	Dry Matter	Digestible Pro.	Digestible C-H	Digestible Fat
1	.11	.008	.08	.002	1	.21	.011	.16	.001
2	.23	.016	.16	.004	2	.42	.022	.31	.002
3	.34	.024	.23	.006	3	.63	.033	.47	.003
4	.46	.032	.31	.008	4	.84	.044	.63	.004
5	.57	.040	.39	.010	5	1 04	.055	.78	.005
6	.68	.048	.47	.012	6	1 25	.066	.94	.006
7	.80	.056	.55	.114	7	1 46	.077	1.10	.007
8	.91	.064	.62	.016	8	1.67	.088	1.26	.008
9	1.03	.072	.70	.018	9	1.88	.099	1.41	.009
10	1.14	.080	.80	.020	10	2 09	.110	1.57	.010
Sugar Beet					**Common Beet**				
1	.13	.013	.10	.001	1	.11	.012	.08	.001
2	.27	.026	.20	.002	2	.23	.024	.16	.002
3	.40	.039	.29	.003	3	.34	.036	.24	.003
4	.54	.052	.39	.004	4	.46	.048	.32	.004
5	.67	.065	.49	.005	5	.57	.060	.39	.005
6	.81	.078	.59	.006	6	.69	.072	.47	.006
7	.94	.091	.69	.007	7	.80	.084	.55	.007
8	1.08	.104	.78	.008	8	.92	.096	.63	.008
9	1.21	.117	.88	.009	9	1.03	.108	.71	.009
10	1.35	.130	.98	.010	10	1.15	.120	.79	.010
Mange					**Rutabaga**				
1	.09	.010	.05	.002	1	.11	.010	.08	.002
2	.18	.020	.11	.004	2	.23	.020	.16	.004
3	.27	.030	.16	.006	3	.34	.030	.24	.006
4	.36	.040	.22	.008	4	.46	.040	.32	.008
5	.45	.050	.27	.010	5	.57	.050	.40	.010
6	.55	.060	.33	.012	6	.68	.060	.49	.012
7	.64	.070	.38	.014	7	.80	.070	.57	.014
8	.73	.080	.44	.016	8	.91	.080	.65	.016
9	.82	.090	.49	.018	9	1.03	.090	.73	.018
10	.91	.100	.55	.020	10	1.14	.100	.81	.020
Flat Turnip					**Wet Beet Pulp**				
1	.10	.009	.06	.001	1	.10	.005	.08	.000
2	.20	.018	.13	.002	2	.20	.010	.15	.000
3	.30	.027	.19	.003	3	.31	.015	.23	.000
4	.40	.036	.26	.004	4	.41	.020	.31	.000
5	.49	.045	.32	.005	5	.51	.025	.38	.000
6	.59	.054	.38	.006	6	.61	.030	.46	.000
7	.69	.063	.45	.007	7	.71	.035	.54	.000
8	.79	.072	.51	.008	8	.82	.040	.62	.000
9	.89	.081	.58	.009	9	.92	.045	.69	.000
10	.99	.090	.64	.010	10	1.02	.050	.77	.000

Table III. Pounds of Dry Matter and Nutrients Contained in a Given Number of Pounds of Feed Stuff.

CONCENTRATES—Ground Grains and By-Products

Lbs.	Dry Matter	Digestible Pro.	Digestible C-H.	Digestible Fat	Lbs.	Dry Matter	Digestible Pro.	Digestible C-H.	Digestible Fat
Corn					**Barley**				
1	.89	.079	.67	.043	1	.89	.084	.65	.016
2	1.78	.158	1.33	.086	2	1.78	.168	1.31	.032
3	2.67	.237	2.01	.129	3	2.68	.252	1.96	.048
4	3.56	.316	2.67	.172	4	3.57	.336	2.61	.064
5	4.45	.395	3.33	.215	5	4.46	.420	3.26	.080
6	5.35	.474	4.00	.258	6	5.35	.504	3.92	.096
7	6.24	.553	4.67	.301	7	6.24	.588	4.57	.112
8	7.13	.632	5.34	.344	8	7.14	.672	5.22	.128
9	8.02	.711	6.00	.387	9	8.03	.756	5.88	.144
10	8.91	.790	6.67	.430	10	8.92	.840	6.53	.160
Oats					**Wheat**				
1	.90	.107	.50	.038	1	.89	.088	.67	.015
2	1.79	.214	1.01	.076	2	1.79	.176	1.35	.030
3	2.69	.321	1.51	.114	3	2.68	.264	2.02	.045
4	3.58	.428	2.01	.152	4	3.58	.352	2.70	.060
5	4.48	.535	2.51	.190	5	4.47	.440	3.37	.075
6	5.38	.642	3.19	.228	6	5.37	.528	4.05	.090
7	6.27	.749	3.52	.266	7	6.26	.616	4.72	.105
8	7.17	.856	4.02	.304	8	7.16	.704	5.40	.120
9	8.06	.963	4.53	.342	9	8.05	.792	6.07	.135
10	8.96	1.070	5.03	.380	10	8.95	.880	6.75	.150
Wheat Bran					**Flour Wheat Middlings**				
1	.88	.119	.42	.025	1	.90	.17	.54	.041
2	1.76	.238	.84	.050	2	1.80	.34	1.07	.082
3	2.64	.357	1.26	.075	3	2.70	.51	1.61	.123
4	3.52	.476	1.68	.100	4	3.60	.68	2.14	.164
5	4.40	.595	2.10	.125	5	4.50	.84	2.68	.205
6	5.29	.714	2.52	.150	6	5.40	1.01	3.22	.246
7	6.17	.833	2.94	.175	7	6.30	1.18	3.75	.287
8	7.05	.952	3.36	.200	8	7.20	1.35	4.29	.328
9	7.93	1.071	3.78	.225	9	8.40	1.52	4.82	.369
10	8.81	1.190	4.20	.250	10	9.00	1.69	5.36	.410
Wheat Sorts					**Red Dog Flour**				
1	.89	.130	.46	.045	1	.90	.162	.57	.034
2	1.78	.260	.91	.090	2	1.80	.324	1.14	.068
3	2.66	.390	1.37	.135	3	2.70	.486	1.71	.102
4	3.55	.520	1.83	.180	4	3.60	.658	2.28	.136
5	4.44	.650	2.28	.225	5	4.50	.810	2.85	.170
6	5.33	.780	2.74	.270	6	5.41	.972	3.42	.204
7	6.22	.910	3.20	.315	7	6.31	1.134	3.99	.238
8	7.10	1.040	3.66	.360	8	7.21	1.296	4.56	.272
9	7.99	1.170	4.11	.405	9	8.11	1.458	5.13	.306
10	8.88	1.300	4.57	.450	10	9.01	1.620	5.70	.340

Table III. Pounds of Dry Matter and Nutrients Contained in a Given Number of Pounds of Feed Stuff.

CONCENTRATES—(Cont'd)

Emmer (Speltz)

Lbs.	Dry Matter	Digestible Pro.	Digestible C-H.	Digestible Fat
1	.92	.10	.70	.02
2	1.84	.20	1.41	.04
3	2.76	.30	2.11	.06
4	3.68	.40	2.81	.08
5	4.60	.50	3.51	.10
6	5.52	.60	4.22	.12
7	6.44	.70	4.92	.14
8	7.36	.80	5.62	.16
9	8.28	.90	6.33	.18
10	9.20	1.00	7.03	.20

Corn and Cob Meal

Lbs.	Dry Matter	Digestible Pro.	Digestible C-H.	Digestible Fat
1	.85	.044	.60	.029
2	1.70	.088	1.20	.058
3	2.55	.132	1.80	.087
4	3.40	.176	2.40	.116
5	4.24	.220	3.00	.145
6	5.09	.264	3.60	.174
7	5.94	.308	4.20	.203
8	6.79	.352	4.80	.232
9	7.64	.396	5.40	.261
10	8.49	.440	6.00	.290

Kafir Corn

Lbs.	Dry Matter	Digestible Pro.	Digestible C-H.	Digestible Fat
1	.90	0.52	.44	.014
2	1.80	.104	.89	.028
3	2.70	.156	1.33	.042
4	3.60	.208	1.77	.056
5	4.50	.260	2.21	.070
6	5.41	.312	2.66	.084
7	6.31	.364	3.10	.098
8	7.21	.416	3.54	.112
9	8.11	.468	3.99	.126
10	9.01	.520	4.43	.140

Sorghum Seed

Lbs.	Dry Matter	Digestible Pro.	Digestible C-H.	Digestible Fat
1	.87	.045	.61	.028
2	1.74	.090	1.22	.056
3	2.62	.135	1.83	.084
4	3.49	.180	2.44	.112
5	4.36	.225	3.05	.140
6	5.23	.270	3.67	.168
7	6.10	.315	4.28	.196
8	6.98	.360	4.89	.224
9	7.85	.405	5.50	.252
10	8.72	.450	6.11	.280

Buckwheat Bran

Lbs.	Dry Matter	Digestible Pro.	Digestible C-H.	Digestible Fat
1	.92	.059	.34	.02
2	1.84	.118	.68	.04
3	2.75	.177	1.02	.06
4	3.67	.236	1.36	.08
5	4.59	.295	1.70	.10
6	5.51	.354	2.04	.12
7	6.43	.413	2.34	.14
8	7.34	.472	2.72	.16
9	8.26	.531	3.06	.18
10	9.18	.590	3.40	.20

Buckwheat Middlings

Lbs.	Dry Matter	Digestible Pro.	Digestible C-H.	Digestible Fat
1	.87	.227	.37	.061
2	1.74	.454	.75	.122
3	2.62	.681	1.12	.183
4	3.49	.908	1.50	.244
5	4.36	1.135	1.87	.305
6	5.23	1.362	2.25	.366
7	6.10	1.589	2.62	.427
8	6.98	1.816	3.00	.488
9	7.85	2.043	3.37	.549
10	8.72	2.270	3.75	.610

Rye Bran

Lbs.	Dry Matter	Digestible Pro.	Digestible C-H.	Digestible Fat
1	.88	.112	.47	.018
2	1.77	.224	.94	.036
3	2.65	.336	1.40	.054
4	3.54	.448	1.87	.072
5	4.42	.560	2.34	.090

Rye Middlings

Lbs.	Dry Matter	Digestible Pro.	Digestible C-H.	Digestible Fat
1	.88	.110	.53	.026
2	1.76	.220	1.06	.052
3	2.65	.330	1.59	.078
4	3.53	.440	2.12	.104
5	4.41	.550	2.64	.130

Table III. Pounds of Dry Matter and Nutrients Contained in a Given Number of Pounds of Feed Stuff.

CONCENTRATES—(Cont'd)

Millet					Hominy Feed				
Lbs	Dry Matter	Digestible Pro.	Digestible C-H.	Digestible Fat	Lbs.	Dry Matter	Digestible Pro.	Digestible C-H	Digestible Fat
1	.88	.071	.48	.025	1	.90	.068	.60	.074
2	1.76	.142	.97	.050	2	1.81	.136	1.21	.148
3	2.64	.213	1.45	.075	3	2.71	.204	1.81	.222
4	3.52	.284	1.94	.100	4	3.62	.272	2.42	.296
5	4.39	.355	2.42	.125	5	4.52	.340	3.02	.370

Corn Oil Meal					Bean Meal				
1	.91	.158	.39	.108	1	.89	.202	.42	.013
2	1.83	.316	.78	.216	2	1.78	.404	.85	.026
3	2.74	.474	1.16	.324	3	2.67	.606	1.27	.039
4	3.66	.632	1.55	.432	4	3.56	.808	1.69	.052
5	4.57	.790	1.94	.540	5	4.45	1.010	2.11	.065

Cow Pea Meal					Soy Bean Meal				
1	.85	.168	.55	.011	1	.88	.291	.23	.146
2	1.71	.336	1.10	.022	2	1.77	.582	.47	.292
3	2.56	.504	1.65	.033	3	2.65	.873	.70	.438
4	3.42	.672	2.20	.044	4	3.53	1.164	.93	.584
5	4.27	.840	2.74	.055	5	4.41	1.455	1.16	.730

Gluten Feed					Gluten Meal				
1	.91	.213	.53	.029	1	.90	.297	.42	.061
2	1.82	.426	1.06	.058	2	1.81	.594	.85	.122
3	2.72	.639	1.58	.087	3	2.71	.891	1.27	.183
4	3.63	.852	2.11	.116	4	3.62	1.188	1.70	.244
5	4.54	1.065	2.64	.145	5	4.52	1.485	2.12	.305

Linseed Meal					Cotton-seed Meal				
1	.90	.302	.32	.069	1	.93	.376	.21	.096
2	1.80	.604	.64	.138	2	1.86	.752	.43	.192
3	2.71	.906	.96	.207	3	2.79	1.128	.64	.288
4	3.61	1.208	1.28	.276	4	3.72	1.504	.86	.384
5	4.51	1.510	1.60	.345	5	4.65	1.880	1.07	.480

Flax Seed					Tankage				
1	.91	.206	.17	.290	1	.930	.501	.00	.116
2	1.82	.412	.34	.580	2	1.860	1.002	.00	.232
3	2.72	.618	.51	.870	3	2.790	1.503	.00	.348
4	3.63	.824	.68	1.160	4	3.720	2.004	.00	.464
5	4.54	1.030	.85	1.450	5	4.650	2.505	.00	.580

Table III. Pounds of Dry Matter and Nutrients Contained in a Given Number of Pounds of Feed Stuff.

CONCENTRATES—(Cont'd)

wers' Grain (Dried)					**Malt Sprouts**				
Lbs.	Dry Mat-ter	Digestible			Lbs.	Dry Mat-ter	Digestible		
		Pro.	C-H.	Fat			Pro.	C-H.	Fat
1	.91	.200	.32	.060	1	.90	.203	.46	.014
2	1.83	.400	.64	.120	2	1.81	.406	.92	.028
3	2.74	.600	.97	.180	3	2.71	.609	1.38	.042
4	3.65	.800	1.29	.240	4	3.62	.812	1.84	.056
5	4.56	1.000	1.61	.300	5	4.52	1.015	2.30	.070
Distillery Grain (Dried)					**Dried Beet Pulp**				
1	.92	.228	.40	.116	1	.92	.041	.65	.000
2	1.85	.456	.79	.232	2	1.82	.082	1.30	.000
3	2.77	.684	1.19	.348	3	2.75	.123	1.95	.000
4	3.70	.912	1.59	.464	4	3.66	.164	2.60	.000
5	4.62	1.140	1.98	.580	5	4.58	.205	3.24	.000

How to Formulate a Balanced Ration. The term "balanced ration" means a combination of foods containing such amounts of protein (organic matter containing nitrogen), carbohydrates (nitrogen free material), and fat, as are known to be necessary for the maintenance of the animal body and the production of work, milk, or fatty tissues. All dairy cows should not be fed the same ration, because their requirements for food are very variable. Differences in weight and flow of milk should be considered in preparing their daily food rations. It is unreasonable to think that a 1,400 pound cow giving fifty pounds of milk daily should receive the same ration as a 1,000 pound cow giving twenty pounds of milk daily. The requirements of one cow are greater than those of the other and should be considered in feeding. Profitable feeding of dairy cows demands that records of milk flow be taken for each cow in the herd, and also that the weights of the cows be known. Such data are necessary to successful feeding methods.

The computing of a balanced ration for a dairy cow is accomplished as follows: In case of a 1,200 pound cow yielding 40 pounds of 3.6% milk daily, the daily nutrient requirements for maintenance and milk production are totaled from the data given in Tables I and II.

	Pro. Lbs.	C-H. Lbs.	Fat Lbs.
For maintenance of a 1200 pound cow..........	.840	8.40	.120
For production of 40 lbs. 3.6% milk............	2.004	9.00	.772
Total nutrients required daily..............	2.844	17.40	.892

The next step is to refer to Table III and to compound a mixture of roughage and grain feeds that will approximately meet the known nutrient requirements of the cow, using farm grown feeds as much as possible to reduce the cost of the ration to a minimum. In making up trial rations to get the desired balanced ration, the necessary amount of roughage may be estimated at the rate of two pounds of hay, or its equivalent, for each 100 lbs. of the cow's weight, and one pound of grain for each three pounds of milk yield. When silage is fed, the rule may be to feed one pound of hay and three pounds of silage per hundredweight, and the balance of the required nutrients should be provided in concentrates, except that, when roots are fed, they will take the place of a part of the grain at the rate of ten pounds of roots for one pound of grain. These directions are general and should be used only as a guide in making out trial rations to compare with the known amounts of nutrients required. In feeding practice it will be found that spare, big bodied cows will take relatively more roughage.

Three rations are shown herewith that will meet the nutrient requirements of a 1,200 lb. cow yielding 40 lbs. of 3.6% milk daily:

Ration No. 1

Kind of Feed	Feed Lbs.	Protein Lbs.	C-H. Lbs.	Fat Lbs.
Timothy hay	24	.672	10.42	.336
Ground oats	6	.642	3.19	.228
Wheat bran	4	.476	1.68	.100
Wheat middlings	2	.340	1.07	.082
Linseed meal	2½	.755	.80	.172
Nutrients provided	....	2.885	17.16	.918

Ration No. 2

Kind of Feed	Feed Lbs.	Protein Lbs.	C-H. Lbs.	Fat Lbs.
Clover hay	22	1.562	8.32	.396
Mangels	30	.300	1.65	.060
Ground corn	8	.632	5.34	.344
Ground oats	4	.428	2.01	.152
Nutrients provided	....	2.922	17.32	.952

Ration No. 3

Kind of Feed	Feed Lbs.	Protein Lbs.	C-H. Lbs.	Fat Lbs.
Clover hay	16	1.136	6.05	.288
Corn silage	30	.375	4.26	.210
Ground oats	7	.749	3.52	.266
Ground corn	4	.316	2.67	.172
Linseed meal	1	.302	.32	.069
Nutrients provided	....	2.878	16.82	1.005

Rations numbered 2 and 3 are much better than number 1, because the feed is more succulent and palatable and be-

cause less expensive mill feed is needed to properly balance the ration. Clover, alfalfa, cowpeas, and other legume forage crops, contain a much higher percentage of protein (nitrogenous matter) than such forage crops as timothy, brome grass, or fodder corn. For this reason, when they are used in feeding, they greatly reduce the amount of nitrogenous mill feeds, such as linseed meal, wheat middlings, or cotton seed meal, necessary to balance the ration properly.

Palatability of the Ration. In formulating a ration, due regard should be given to its palatability. When a cow relishes her food, the appetite is stimulated, digestion aided, and she gives better returns. To this end, forage should be cut early and not exposed to sunshine any longer than is absolutely necessary. Dews and sunlight in alternation will bleach forage, and reduce its palatability and digestibility. The ration should be composed of a reasonable number of feeds, since a mixture is relished better than only one kind of grain or roughage; but frequent changes in a ration should be avoided, as they cause imperfect digestion and assimilation.

The dairyman should so adjust the supply of feed that the ration can be made from two kinds of roughage and several varieties of grain, and then make no more changes during the winter than are necessary. If an appetizing, well balanced ration can be fed all winter, better results will be obtained than when changes in the ration are made. Succulent feed, such as roots and silage, is greatly relished, and it stimulates the appetite and the flow of milk. It also aids digestion by keeping the cow in better physical tone.

NOTE: Tables taken exactly from Bulletin 130 of the Minnesota Agr. Expt. Station. Explanation of how to formulate a balanced ration by the author—this being an epitome of Bulletin 130.

THE WOLFF FEEDING STANDARDS FOR FARM ANIMALS

(From Henry's Feeds and Feeding)

Kind of Live Stock	Lbs. per day per 1,000 lbs. live weight					
		Digestible Nutrients				
	Dry matter	Crude pro.	C-H.	Fat	Sum Nutri-ents	Nutri-tive Ratio
1. Fattening cattle—						
First period	30	2.5	15.0	0.5	15.6	6.5
Second period	30	3.0	14.5	0.7	17.0	5.4
Third period	26	2.7	15.0	0.7	17.2	6.2
2. Breeding ewes, with lambs	25	2.9	15.0	0.5	16.3	5.6
3. Fattening sheep—						
First period	30	3.0	15.0	0.5	16.5	5 4
Second period	28	3.5	14.5	0.6	16.9	4.5
4. Horses—						
Light work	20	1.5	9.5	0.4	10.0	7.0
Medium work	24	2.0	11.0	0.6	12.8	6 2
Heavy work	26	2.5	13.3	0.8	15.5	6.0
5. Brood sows	22	2.5	15.5	0.4	19.0	6.6
6. Fattening swine—						
First period	36	4.5	25.0	0.7	31.2	5.9
Second period	32	4.0	24.0	0.5	29.2	6.3
Third period	25	2.7	18.0	0.4	22.0	7.0
7. Growing cattle—Dairy breeds						
Age, Months — Av. Live Wt.						
2–3 — 160	23	4.2	13.0	2.0	21.5	4.2
3–6 — 330	24	3.5	12.8	1.5	19.0	4.7
6–12 — 550	25	2.5	13.2	0.7	15.8	6.0
12–18 — 750	24	2.0	12.5	0.5	13.9	6.8
18–24 — 950	24	1.8	12.0	0.4	13.2	7.2
8. Growing sheep—Mutton breeds						
4–6 — 60	26	4.4	15.5	0.9	20.9	4.0
6–8 — 80	26	3.5	15.0	0.7	17.8	4.8
8–11 — 100	24	3.0	14.3	0.5	16.3	5.2
11 15 — 120	23	2.2	12.6	0.5	13.8	6.3
15–20 — 150	22	2.0	12.0	0.4	12.8	6.5
9. Growing swine—Breeding stock						
2–3 — 50	44	7.6	28 0	1.0	38.0	4.0
3–5 — 100	35	4.8	22.5	0.7	29.0	5.0
5–6 — 120	32	3.7	21.3	0.4	26.0	6.0
6–8 — 200	28	2.8	18.7	0.3	22.2	7.0
8–12 — 250	25	2.1	15 3	0.2	17.9	7.5

NOTE: Balanced rations for these kinds of farm animals may be computed from the forage crop and grain feed analyses shown under the Haecker Feeding Standards, and by similar methods, using the Wolff Standards as the basis for nutrients required.

COST OF FARM HORSE POWER

Agricultural Region	Total Annual Cost of Keeping One Horse. Average 5 years 1908-1912	Actual Cost per Hour of Work for One Horse. Average 9 years 1904-1912
Southeastern Minnesota...........	$103.27	9.72 cents
Southwestern Minnesota..	100.64	(*) 8.64 cents
Northwestern Minnesota...........	84.67	8.05 cents

(*) 7 year average.

NOTE: The cost figures shown in this table have been selected from the statistical data of the Division of Farm Management of the Minnesota Agricultural Experiment Station. These figures are not estimates, but actual records from a large number of Minnesota farms. The averages are based on records of about 450 horses in each region. The annual cost includes interest on investment, depreciation, harness depreciation, shoeing, feed, labor, and miscellaneous expense. Feed is the largest item in the cost of farm horse power, representing on the average two thirds to three fourths of the total cost. The cost of horse power per hour is computed by dividing the total annual cost by the actual number of hours worked.

FENCING COSTS

Kind of Fence	Cost per Rod on Basis of a Square 40-Acre Field					
	Cedar Posts			Steel Posts		
	1 Rod Apart	1½ Rods Apart	2 Rods Apart	1 Rod Apart	1½ Rods Apart	2 Rods Apart
	Cents	*Cents*	*Cents*	*Cents*	*Cents*	*Cents*
2 strands barbed wire with temporary, driven, 3″ posts	..	21	18	......	......	......
3 strands barbed wire	37	29	25	52	40	35
35 inch woven wire with 1 strand of barbed wire	53	45	......	69	57	......
26 inch woven wire hog fence with 2 strands barbed wire	62	53..	......	77	65	......

NOTE: Statistics of average costs for fencing materials and labor by courtesy of L. B. Bassett, Minnesota Agricultural Experiment Station; arrangement and cost per rod computations by the author.

The costs of fencing per rod shown in this table include posts, wire, staples and labor. These costs have been computed on the basis of a 40 acre field, and thus the cost for four corner posts has been figured into the average cost per rod. No cost for gates has been included. The posts for the temporary barbed wire fence are 3 inch cedar; all other wooden posts are of 4 inch cedar. Steel post costs are for the hollow type of round, steel post. The temporary 3 inch cedar posts are driven 2 to 2½ feet deep; all other wooden posts are set 2½ feet deep. The steel posts are driven 2½ ft. deep.

Fence cost is very variable in various agricultural regions of the United States, varying with the distance from wire manufacturing centers and with the local supply of post materials. Cedar and oak posts, for example, range in cost all the way from 8 cts. to 22 cts. apiece. The cedar post and the steel post are the posts of commerce and have, therefore, been used in this cost table.

The costs shown in this table are based on the following data, which represent a fair average for the United States.

(1) **Labor.**

Wages for man labor $35.00 per month; board cost $15.00 per month; total of $50.00 per month; or approximately 20 cents per hour for a 10 hour day. Horse labor is figured at 10 cents per hour per horse.

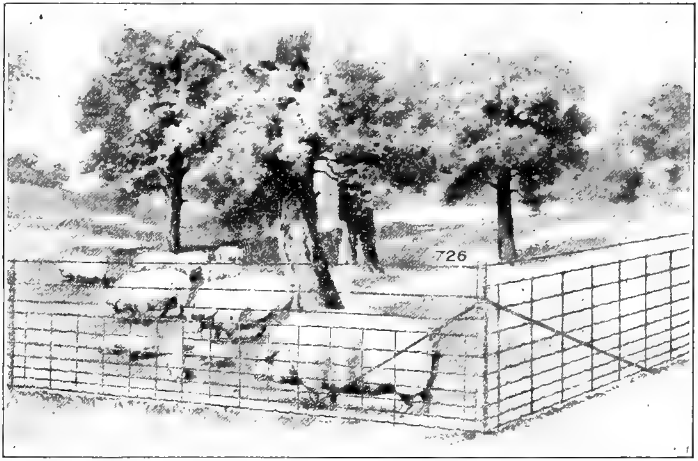


Photo by courtesy American Steel and Wire Company.
Types of woven wire fence with steel line posts, corner posts and braces

In one day of 10 hours, fencing work may be performed at the following rates: 2 men and one team of horses will drive 200 to 250 three inch cedar posts or steel posts in soil free from stone; 2 men, with one hour of team labor, will dig holes and set 80 to 100 four inch posts 2½ feet deep; 2 men will dig holes and set and brace 6 to 10 wooden corner posts; 2 men will dig holes, mix the necessary concrete, and set and brace 4 steel corner posts, set in concrete; 2 men will stretch and staple 80 rods of one strand, new barbed wire, in one hour; 2 men will stretch and staple 80 rods of new woven wire in 3½ to 4 hours.

(2) **Posts.**

Cedar line posts, 3 inches by 7 feet, 15 cents apiece.
Cedar line posts, 4 inches by 7 feet, 18 cents apiece.
Cedar corner posts, 6 inches by 8 feet, 25 cents apiece.
Steel line posts, round, galvanized, 7 feet, 32 cents apiece.

Steel corner posts, round, galvanized, 7 feet 8 inches, with all braces included, $2.90 apiece.

(3) **Wire.**

Barbed wire, $3.00 per roll of 105 lbs. One roll will run about 80 rods, giving a cost per rod for one strand of 3¾ cents.

Woven wire, 35 inches high, with 12 inch stays, No. 9 wire top and bottom, No. 11 wire intermediate, 23 cents per rod.

Hog fence, woven wire, 26 inches high, with 6 inch stays, No. 9 wire top and bottom, No 11 wire intermediate, 27 cents per rod.

(4) **Staples.**

$2.50 per keg of 100 lbs. Staples run 80 to 90 per pound. In stapling woven wire it takes about 7½ lbs. staples for 100 rods of 35 inch fence with posts 1 rod apart.

WORK CAPACITY OF FARM MACHINES

Kind of Machine	Size of Machine	Horse Power Required	Speed per Hour in Miles, or Revolutions per Minute	Acre Capacity per Hour	Ton or Bushel Capacity per Hour
			Miles		
Binder, small grain	6′ cut	3	2½	1.5–1.8	
Binder, small grain	7′ cut	4	2½	1.7–2.1	
Binder, small grain	8′ cut	4	2½	2.0–2.4	
Binder, corn		3–4	2½	.8–1.0	
Cultivator, single row, (42″ rows)		1	2	.5– .8	
Cultivator, riding (42″ rows)		2	2	.5– .8	
Cultivator, 2 row riding (42″ rows)		3–4	2	1.0–1.6	
Drill, small grain	12 tube	2	2½	1.5–1.8	
Drill, small grain	16 tube	3	2½	2.0–2.4	
Drill, small grain	20 tube	4	2½	2.5–3.0	Tons
Ensilage cutter, with fly wheel diameter of	42 inch	15–20			9–15
Ensilage cutter, with fly wheel diameter of	36 inch	12–15			8–12
Ensilage cutter, with fly wheel diameter of	30 inch	8–12			5– 8
Harrow, disk (½ lapped)	4 foot	2	2	.4– .5	
Harrow, disk (½ lapped)	6 foot	3	2	.6– .7	
Harrow, disk (½ lapped)	8 foot	4	2	.8–1.0	
Harrow, spring tooth	6 foot	3	2	1.0–1.4	
Harrow, spring tooth	8 foot	4	2	1.5–2.0	
Harrow, spike tooth	3 sec.	2–3	2	3.0–3.6	
Harrow, spike tooth	5 sec.	4	2	5.0–6.0	
Header, small grain	12 foot	6	2½	3.0–3.6	
Mower	5 foot	2	2½	1.2–1.5	
Mower	6 foot	2	2½	1.5–1.8	
Packer	10 foot	4	2	2.0–2.4	
Planter, beet (18″ rows)	4 row	2	2½	1.5–1.8	
Planter, corn, 1 row (42″ rows)		1	2½	.5–1.0	
Planter, corn, 2 rows (42″ rows)		1	2½	1.0–2.0	
Planter, potato, 1 row (40″ rows)		2	2½	.6–1.0	
Planter, potato, 2 rows (40″ rows)		4	2½	1.2–2.0	
Plow, walking	14″ cut	2	2½	.25–.35	
Plow, walking	16″ cut	3	2½	.3–.4	
Plow, sulky	16″ cut	3	2½	.3–.4	
Plow, sulky gang	28″ cut	4–5	2½	.5–.7	
Plow, engine gang, 4 plows	56″ cut	14–18	2	.9–1.1	
Plow, engine gang, 6 plows	84″ cut	20–25	2	1.4–1.6	
Plow, engine gang, 8 plows	112″ cut	25–30	2	1.9–2.2	
Plow, deep tillage, 2 disk	20″ cut	6	2	.34–.4	
Potato digger, 40″ rows		4	2½	.7–1.0	
Rake, self dump	10 foot	2	2½	2.5–3.0	
Rake, side delivery	8 foot	2	2½	2.0–2.4	Bushels
Shredder and husker (corn)	4 roll	10–12			25–50
Shredder and husker (corn)	6 roll	15–20	Revo-		50–75
Shredder and husker (corn)	8 roll	25	lutions		80–100
Threshing separator (pea and bean special)	12 inch	2–4	300–350		8–10
Threshing separator (pea and bean special)	20x32 "	6–8	300–350		35–50
Threshing separator (pea and bean special)	26x44 "	10–14	300–350		50–80
Threshing separator (pea and bean special)	36x54 "	14–18	300–350		80–100
Threshing separator, small grain (wheat and flax)	18x36 "	15–18	1050–1150		60

Work Capacity of Farm Machines—Continued

Kind of Machine	Size of Machine	Horse Power Required	Revolutions per Minute	Acre Capacity per Hour	Bushel Capacity per Hour
Threshing separator (oats and barley) ...	18x36 "	15–18	1050–1150	....	220
Threshing separator (wheat and flax) ...	28x50 "	30–40	750–800	....	75
Threshing separator (oats and barley) ...	28x50 "	30–40	750–800	....	275
Threshing separator (wheat and flax) ...	32x54 "	40–50	750–800	....	125
Threshing separator (oats and barley) ...	32x54 "	40–50	750–800	....	300
Threshing separator (wheat and flax) ...	36x58 "	50–60	750–800	....	160
Threshing separator (oats and barley) ...	36x58 "	50–60	750–800	....	350
Threshing separator (wheat and flax) ...	40x62 "	60–80	750–800	....	200
Threshing separator (oats and barley)	40x62 "	60–80	750–800	.....	375

NOTE: Data on ensilage cutters and shredders by courtesy of The International Harvester Co.; pea threshers, J. L. Owens Mfg. Co.; grain separators, J. I. Case Threshing Machine Co.; all other data by the author.

Horse power for engine plows is horse power at the drawbar; for threshing machines, shredders, and ensilage cutters, horse power on the belt.

The work capacity of farm machines varies through very wide limits, due to soil and crop conditions, speed and stamina of horses, size and shape of fields, condition of the machine to stand steady work, and the experience and character of the operator. In this table there is shown the maximum capacity per hour for the common tillage, planting and harvesting machines, at the standard speeds for best work; also the average capacity per hour based on observations of the actual average daily capacity of farm machines.

The actual, average work capacity of any farm machine may be determined very closely by subtracting 15% to 20% from the maximum capacity at a given speed—this deduction being made for time lost in turning, resting horses, oiling, adjusting, filling seed hoppers, etc.; or in case of power machinery for oiling, adjusting, and taking fuel. The capacity of certain machines such as the corn binder and the potato digger are especially subject to variation. For best results these machines must be driven at comparatively high speed (2½-3 miles per hour) and this speed quickly tires the horses. In order to maintain maximum capacity it is necessary to change horses once or twice a day. If the horses are not changed the capacity varies greatly according to the amount of rest allowed.

THE DEPRECIATION IN VALUE OF FARM MACHINERY

(From Bulletin 73, Bureau of Statistics, U. S. Dept. of Agriculture)

Annual Depreciation in Value of Farm Machinery Expressed in Percentages.

Machine	S. E. Minn.	S. W. Minn.	N. W. Minn.	1,820 Ac. Farm N. W. Minn.	640 Ac. Farm W. Minn	Average, All Machines
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Grain binders	8.33	9.44	7.47	6.53	10.57	7.91
Grain drills and seeders	7.27	8.07	6.53	4.36	6 47	6.75
Thrashing outfit	......	......	......	12.00	......	12.00
Corn binders	11.46	10.16	11.40	......	9.00	10.03
Corn planters	6.74	8.54	......	......	......	7.15
Corn cultivators	6.67	9.04	6.97	4.66	5.00	7.25
Mowers	7.25	10.01	6.97	7.28	8.93	7.80
Hay tedders	4.84	......	......	......	......	4.84
Hay loaders	11.78	......	......	......	......	11.78
Hay rakes	7.68	7.51	8.46	5.81	5.00	7.80
Gang plows	10.51	7.16	6.69	8.46	6.71	7.40
Sulky plows	10.27	11.93	5 77	......	3.70	8.42
Walking plows	4.77	7.29	7.64	......	8.82	6.09
Wagons	6.66	4.86	5.44	2.47	5.90	4.89
Harrows	11.01	8.20	7.93	8.89	6.78	8.72
Disks	5.41	7.46	......	3.35	7.50	5.19
Manure spreaders	10.50	12.59	......	......	10.00	11.67
Hay racks	14.57	14.89	10.30	5.12	......	7.76
Reapers	......	......	......	8.13	......	8.13
Grain tanks	......	......	......	3.47	......	3.47
Sleds	5.66	4 50	6.82	8.20	......	5.81
Fanning mills	5.00	4.97	......	3.66	3.33	4.58
Horse weeders	......	......	......	......	5.71	5.71
Harness (heavy)	5.97	6.63	7.21	......	4.44	6.17
Gasoline engines	3.92	......	......	......	10.00	7.35

Values in Farm Machinery Consumed per Acre Annually, 1902-1907.

Machinery	S. E. Minn.	S. W. Minn.	N. W. Minn.	1,820 Ac. Farm N. W. Minn.	640 Ac. Farm W. Minn.	Average, All Farms
Grain machinery:						
Binders	$0.240	$0.247	$0.160	$0.135	$0.175	$0.181
Reapers	....	....	....	.171	....	.171
Drills, seeders	.104	.101	.077	.036	.075	.075
Fanning mills	.019	.016	....	.004	.016	.010
Grain tanks	....	....	....	.012	....	.011
Wagons, sleds, and racks	.041	.041	.036	.023	....	.034
Corn machinery:						
Binders	1.199	.911	.653	....	.251	.826
Planters	.094	.080	....	....	....	.087
Cultivators	.171	.145	.218	....	.086	.155
Wagons, sleds, and racks	.171	.159	.100	....	....	.158
Hay machinery:						
Mowers	.332	.310	.150	.146	.166	.206
Rakes	.152	.106	.081	.018	.026	.085
Tedders	.113	....	....	....	....	.113
Loaders	.300	....	.100	....	....	.151
Ropes, forks, etc.	.078	.200	....	....	....	.120
Wagons, sleds, and racks	.064	.061	.059	.036	....	.059
All crop machinery:						
Plows	.086	.132	.078	.061	.119	.087
Harrows	.027	.021	.017	.006	.024	.017
Disks	.185	.097	....	....	.032	.089
Thrashing outfit	....	....	....	.335	....	.335

NOTE: These data relative to farm machinery were collected in four farming communities of Minnesota by very careful methods. On about ten farms in each community inventories of machinery were taken annually for five years and the rate of depreciation computed. An accurate record of the acreage covered by farm machines was also made in order to determine an approximate cost per acre for machinery. It was found that the acreage covered by a machine is not as important a factor in depreciation as age.

COST OF PRODUCING CORN, WHEAT, OATS, BARLEY, AND POTATOES IN VARIOUS GEOGRAPHIC DIVISIONS OF THE UNITED STATES.

(From the "Crop Reporter," Bureau of Statistics, U. S. Department of Agriculture.)

Cost of Producing Corn in 1909, by Geographical Divisions.

Item	United States	North Atlantic States	South Atlantic States	South Central States	North Central east of Mississippi River	North Central west of Mississippi River	Far Western States
Cost per acre for:—							
Commercial fertilizer, dollars	0 82	2 91	2.57	0.79	0 55	0.19	0 12
Preparation of land ... " ..	2.11	4.42	2.36	1.96	2 51	1.74	2.26
Seed .... " .	.24	.32	.24	.23	.25	.23	.24
Planting . . " .	44	.74	.56	.47	.36	.38	.65
Cultivation . . . .. " .	2 24	2.81	2.80	2.54	2.11	1.80	1.81
Gathering. ... " .	2 20	5.00	2.24	1.65	2.86	2.06	2 51
Miscellaneous.. . . " .	.47	.62	.52	.48	46	.42	.67
Land rental or interest.. " ..	3 75	3.62	3 14	3.17	4.97	3.76	3.40
Total cost per acre, excluding rent.....dollars	8.52	16.82	11.29	8.12	9 10	6.82	8 26
Including rent,.....dollars	12.27	20.44	14.43	11.29	14.07	10.58	11.66
Yield per acre .. ..bushels	32.40	43.10	25.70	25.20	42 60	34.10	27.60
Cost, excluding rent, per bushel ....cents	26.30	39.00	43.90	32.20	21.40	20 00	29.90
Cost, including rent, per bushel ....cents	37.90	47 40	56.10	44.80	33.00	31.00	42 20
Value per bushel......... cents	62.00	70.00	85.60	67.60	55.00	51.90	74.30
Average value of corn lands per acre................dollars	59.46	62.72	30.60	31.37	98.72	70.80	54.57

Tabulated from the reports of 6000 correspondents of the Bureau of Statistics.

Cost of Producing Wheat in 1909, by Geographical Divisions.

Item	United States	North Atlantic States	South Atlantic States	South Central States	North Central east of Mississippi River	North Central west of Mississippi River	Far Western States
Cost per acre for:							
Commercial fertilizer, dollars	0.58	2.81	2.59	0.57	1.00	0.12	0.17
Preparation of land..... " ..	2.11	3.86	2.47	1.89	2.58	1.79	2.39
Seed................. " ..	1.42	2.01	1.52	1.22	1.60	1.36	1.32
Planting............. " ..	0.46	0.60	0.62	0.46	0.41	0.42	0.53
Harvesting........... " ..	1.33	1.82	1.33	1.25	1.25	1.26	1.68
Preparing for market... " .	1.48	1.69	1.26	1.48	1.49	1.42	1.89
Miscellaneous .... " ..	0.48	0.63	0.47	0.42	0.44	0.44	0.75
Land rental or interest. " ..	3.30	3.63	2.85	3.06	4.63	2.93	3.97
Total cost per acre excluding rent ......dollars	7.85	13.42	10.25	7.29	8.78	6.82	8.72
Including rent,....... " ..	11.15	17.05	13.10	10.35	13.41	9.74	12.69
Yield per acre.........bushels	17.2	20.7	15.7	14.4	18.7	15.8	24.3
Cost, excluding rent, per bushel ....cents	46	65	66	51	47	44	36
Cost, including rent, per bushel ....cents	66	82	85	72	72	62	52
Value per bushel.......... " .	96	103	109	98	98	95	90
Average value of wheat lands per acre............dollars	54.59	63.18	36.66	36.60	85.65	50.24	58.81

Tabulated from the reports of 5000 correspondents of the Bureau of Statistics.

Cost of Producing Oats in 1909, by Geographical Divisions.

Item	United States	North Atlantic States	South Atlantic States	North Central east of Mississippi River	North Central west of Mississippi River	South Central States	Far Western States
	Dols.	*Dols.*	*Dols.*	*Dols.*	*Dols.*	*Dols.*	*Dols.*
Cost per acre for:—							
Commercial fertilizers	.40	1.94	1.97	.33	.08	.41	.07
Preparation of land	1.88	3 52	1.97	1.99	1.46	1.68	2.43
Seed	1.12	1.48	1.22	1.10	1.06	1.03	1 16
Planting	.44	.68	.65	.40	.39	.50	.58
Harvesting	1.34	1.99	1.22	1.27	1.27	1.32	1.65
Preparing for market	1.51	1.80	1.23	1.43	1.46	1.58	2.16
Miscellaneous expense	.44	.58	.40	.39	.44	.40	.66
Land rental or interest on land investment	3.78	3.28	2.80	4.57	3.44	2.89	3.87
Total cost per acre:							
Excluding rent	7.13	11.99	8.66	6.91	6.16	6.92	8.71
Including rent	10.91	15.27	11.46	11.48	9.60	9.81	12.58
Yield per acre.......bushels	35.2	37.3	26.3	37.2	33 5	31.3	43.7
Cost per bushel:							
Excluding rent	.20	.32	.33	.19	.18	.22	.20
Including rent	.31	.41	.44	.31	.29	.31	.29
Value of grain per bu	.40	.50	.64	.38	.36	.48	.50
Value of oat lands per acre	70.48	55.90	29.33	89.86	68.10	30.67	56.66

Tabulated from reports of 5,000 correspondents of the Bureau of Statistics.

Cost of Producing Barley in Important Barley States, 1909.

Item	United States	New York	Wisconsin	Minnesota	Iowa	North Dakota	South Dakota	Nebraska	California
Cost per acre for—									
Preparing ground for seed.................dollars	1.84	3.71	2.22	1.83	1.25	1.83	1.61	0.97	1.77
Seed ... "	1.14	1.96	1.38	1.21	1.22	.97	1.02	.89	.95
Sowing ... "	.46	.65	.69	.42	.36	.46	.37	.48	.44
Harvesting ... "	1.28	2.00	1.58	1.22	1.37	.99	1.15	.93	1.42
Preparing for market. "	1.50	2.58	1.60	1.38	1.25	1.69	1.26	1.04	1.75
Rental value of land.. "	3.17	2.87	4.16	2.67	4.80	2.36	2.73	2.43	3.20
Other items of cost. "	.66	.72	.73	.62	.39	.29	.49	.29	.93
Total cost per acre—									
Including item of rental"	10.05	16.28	12.49	9.43	10.64	8.59	8.71	7.24	10.46
Excluding item of rental"	6.88	13.41	8.33	6.76	5.84	6.23	5.98	4.81	7.26
Yield per acre.....bushels	27.6	41.0	30.0	25.0	28.0	25.0	24.0	23.0	33.0
Cost per bushel—									
Including rental.....cents	36.4	39.7	41.6	37.7	38.0	34.4	36.3	31.5	31.7
Excluding rental..... "	24.9	32.7	27.8	27.0	20.9	24.9	24.9	20.9	22.0
Value of grain—									
Per bushel.......... "	52.1	67.0	60.0	51.0	54.0	47.0	51.0	45.0	50.0
Value of land per acre.doll'rs	65.47	45.83	77.43	51.00	106.36	33.96	52.08	40.00	62.06

Tabulated from reports of 200 correspondents of the Bureau of Statistics.

Cost of Producing Potatoes in 1909, by Geographical Divisions.

Item	United States	North Atlantic States	South Atlantic States	North Central east of Mississippi River	North Central west of Mississippi River	South Central States	Far Western States
Cost per acre for:—	*Dols.*	*Dols.*	*Dols.*	*Dols.*	*Dols.*	*Dols.*	*Dols.*
Commercial fertilizers	3.29	9.01	5.62	1.07	0.40	1.94	0.46
Preparing ground for seed	3.38	4.72	3.20	3.28	2.22	2.41	3.42
Seed	5.36	5.90	5.84	4.38	5.44	6.49	5.70
Planting	2.39	2.58	2.46	2.10	2.44	2.12	2.84
Cultivating	3.15	3.83	3.20	2.96	2.44	2.88	3.73
Gathering	5.77	6.73	4.41	5.28	5.64	4.25	7.02
Rental value of land	3.99	3.85	3.87	4.15	3.66	3.84	4.87
Other items of cost	1.71	2.20	1.50	1.37	1.26	1.60	2.76
Total cost per acre including rental value of land	29.04	38.82	30.10	24.59	23.50	25.53	30.80
Excluding rental value of land	25.05	34.97	26.23	20.44	19.84	21.69	25.93
Yield per acre........bushels	118	138	111	115	102	84	137
Cost per bushel:							
Including rental value of land ....cents	24.6	28.1	27.1	21.4	23.0	30.4	22.5
Excluding rental value of land....cents	21.2	25.3	23.6	17.8	20.0	25.8	18.9
Value of product per bushel, ...cents	53	53	60	46	53	71	64
Value of land per acre.dollars	64.20	62.07	44.76	71.06	68.25	35.35	74.23

Tabulated from reports of 4,000 correspondents of the Bureau of Statistics.

SUMMARY OF THE COST OF PRODUCING FIELD CROPS IN MINNESOTA

(From Bulletin 73, Bureau of Statistics, U. S. Dept. of Agriculture.)

Average Annual Cost per Acre of Producing Field Crops, 1902-1907.

(Including rental of land.)

Crop	S. E. Minn.	S. W. Minn.	N. W. Minn.	Minnesota Agricultural Experiment Station	Large Farm, Northwestern Minnesota	Average, All Farms
Barley—fall plowed	$9.647	$8.880	$7.003	....	$6.179	$8.211
Clover—cut for seed	6.500	......	......	......	......	6.500
Corn—ears husked from standing stalks	11.658	9.662	......	......	......	10.438
Corn—cut, shocked, and shredded	15.297	......	......	......	......	15.297
Corn—cut, shocked, and hauled in from the field	......	10.265	......	......	......	10.265
Corn—grown thickly and siloed	20.627	......	......	19.187	......	19.892
Flaxseed—thrashed from windrow	10.072	......	7.272	......	6.283	7.496
Flaxseed—stacked from windrow	......	8.861	7.028	......	......	7.851
Flaxseed—bound, shocked, stack- and thrashed	......	8.400	6.895	......	......	7.278
Fodder corn—cut and shocked in field	10.733	......	8.912	......	7.896	9.650
Fodder corn—cut, shocked, and stacked	12.362	......	......	......	......	12.362
Hay—timothy and clover (first crop)	6.185	5.553	4.567	......	......	5.591
Hay—timothy and clover (two cuttings)	7.178	......	......	......	......	7.178
Hay—millet	9.317	7.971	6.349	......	......	7.105
Hay—wild grasses	6.036	5.478	2.970	......	2.584	4.042
Hay—timothy	......	......	......	......	3.394	3.394
Hemp	6.741	......	......	......	......	6.741
Mangels	......	......	......	32.682	......	32.682
Oats—fall plowed	9.854	9.039	7.110	......	6.073	8.863
Oats—on disked corn stubble	9.158	8.092	......	......	......	8.884
Potaotes—machine production	......	......	......	......	26.366	26.366
Potatoes—machine production (use of fertilizer)	......	......	......	......	37.721	37.721
Timothy—cut for seed	5.985	5.512	4.310	......	3.432	4.332
Wheat—fall plowed	9.861	8.389	6.977	......	6.056	7.249

NOTE: These summarized figures on the costs of crop production in Minnesota include a land rental charge of $3.50 per acre for lands in S. E. Minn.; $3.00 per acre for S. W. Minn.; and $1.80 per acre for the large farm in N. W. Minn. Land values have risen greatly in these communities since 1902-1907, and land rentals as an item of crop cost are therefore considerably higher. This item of crop cost may be figured into the data of this table for any community by computing the current interest rate on the market value of the land. Labor and seed have also increased in cost since the period 1902-1907. This increase amounts to approximately 20%.

ITEMIZED ACCOUNTS OF THE COSTS OF PRODUCING CORN, HAY, WHEAT, AND POTATOES IN MINNESOTA

(From Bulletin 73, Bureau of Statistics, U. S. Dept. of Agriculture.

Cost of Producing Corn—Ears Husked from Standing Stalks.

Item	S. E. Minn.		
	Total Acreage, Five Years	Total Cost	Cost per Acre
Seed	694.725	$157.290	$0.226
Shelling seed	559.545	14.400	.026
Plowing	803.331	1,053.520	1.311
Dragging	990.448	538.977	.544
Planting (horse planter)	834.228	200.602	.240
Cultivating	960.388	1,734.079	1.806
Weeding	....	....	....
Husking	446.430	1,542.824	3.456
Machinery cost	....	....	.549
Land rental	....	....	3.500
Total	....	....	11.658

Cost of Producing Fodder Corn Planted Thick for Forage—Cut, Shocked, and Stacked in the Farmstead.

Item	S. E. Minn.		
	Total Acreage, Five Years	Total Cost	Cost per Acre
Seed	371.194	$161.960	$0.436
Plowing	803.331	1,053.520	1.311
Dragging	372.844	198.071	.531
Planting (horse planter)	344.005	101.367	.295
Cultivating	353.904	431.009	1.218
Cutting (corn binder)	334.128	232.697	.696
Shocking and tying	334.128	169.984	.509
Twine	298.632	145.970	.489
Hauling and stacking	246.225	401.217	1.629
Machinery cost	....	....	1.748
Land rental	....	....	3.500
Total	....	....	12.362

Cost of Producing Corn—Cut, Shocked, and Shredded.

Item	S. E. Minn.		
	Total Acreage, Five Years	Total Cost	Cost per Acre
Seed	694.725	$157.290	$0.226
Shelling seed	559.545	14.400	.026
Plowing	803.331	1,053.520	1.311
Dragging	990.448	538.977	.544
Planting (horse planter)	834.228	200.602	.240
Cultivating	960.388	1,734.079	1.806
Cutting (corn binder)	367.399	267.547	.728
Shocking and tying	343.579	175.050	.509
Twine	321.499	143.710	.447
Picking up ears	139.230	34.600	.249
Shredding	181.164	717.929	3.963
Machinery cost	....	....	1.748
Land rental	....	....	3.500
Total	....	....	15.297

Cost of Producing Corn—Thickly Planted and Siloed. Average of Four Farms in Southeastern Minnesota, 1906-1907.

Item	Total Acreage	Total Cost	Cost per Acre
Seed	371.194	$161.960	$0.436
Plowing	803.331	1,053.520	1.311
Harrowing	372.844	198.071	.531
Planting	344.005	101.367	.295
Cultivating	353.904	431.009	1.218
Cutting (binder)	82.89	62.520	.754
Twine (432½ pounds)	82.89	44.120	.532
Loading and hauling, feeding and packing	82.89	447.100	5.394
Fuel (coal, 13,730 pounds)	70.89	37.940	.535
Engine rent and engineer	70.89	96.340	1.359
Values consumed in ensilage cutter	15.00	12.830	.855
Interest on silo investment	82.50	60.120	.729
Silo depreciation	82.50	117.990	1.430
Farm machinery cost	....	....	1.748
Land rental	....	....	3.500
Total	....	....	20.627

Cost of Producing Hay—Timothy and Clover.
First Crop

Item	S. E. Minn.		
	Total Acreage, Five Years	Total Cost	Cost per Acre
Seed	....	....	$0.293
Mowing	793.706	$291.705	.368
Raking	618.474	109.977	.178
Cocking and spreading	624.645	124.500	.199
Hauling in	591.514	650.056	1.099
Hauling in and stacking	....	....	....
Machinery cost	....	....	.548
Land rental	....	....	3.500
Total first crop	....	....	6.185

Item	S. W. Minn.		
	Total Acreage, Five Years	Total Cost	Cost per Acre
Seed	....	....	$0.293
Mowing	260.204	$85.352	.328
Raking	260.204	55.407	.213
Cocking and spreading	....	....	....
Hauling in	....	....	....
Hauling in and stacking	260.204	323.135	1.242
Machinery cost	....	....	.477
Land rental	....	....	3.000
Total first crop	....	....	5.553

Cost of Producing Hay—Timothy and Clover—Continued.

First Crop—Continued

Item	N. W. Minn.		
	Total Acreage, Five Years	Total Cost	Cost per Acre
Seed	....	....	$0.293
Mowing	417.647	$151.637	.363
Raking	287.250	71.169	.248
Cocking and spreading	....	....	....
Hauling in	....	....	....
Hauling in and stacking	369 202	470.047	1.273
Machinery cost	....	....	.290
Land rental	....	....	2.100
Total first crop	....	....	4.567

Second Crop

Item	S. E. Minn.		
	Total Acreage, Five Years	Total Cost	Cost per Acre
Mowing	245.090	$64.734	$0.264
Raking	231.090	26.580	.115
Cocking and spreading	89.502	13.448	.150
Hauling in	128.230	59.506	.464
Total second crop	....	....	.993
Total cost of two cuttings	....	....	7.178

Cost of Producing Spring Wheat—Fall Plowed.

Item	S. E. Minn.		
	Total Acreage, Five Years	Total Cost	Cost per Acre
Seed	41.697	$56.280	$1.350
Cleaning seed	....	....	....
Plowing	4,773.396	5,996.560	1.256
Dragging	41.697	9.984	.239
Seeding	41.697	15.485	.371
Weeding	....	....	....
Cutting (binder)	41.697	19.182	.460
Twine	41.697	11.950	.287
Shocking	41.697	9.100	.218
Stacking	11.430	9.021	.789
Stack thrashing (labor)	11.430	6.037	.528
Thrashing, cash cost	11.430	3.960	.346
Machinery cost	....	....	.517
Land rental	....	....	3.500
Total	....	....	9.861

Item	S. W. Minn.		
	Total Acreage, Five Years	Total Cost	Cost per Acre
Seed	3,891.984	$3,909.910	$1.005
Cleaning seed	455.586	15.890	.035
Plowing	5,973.625	6,814.320	1.141
Dragging	4,204.806	722.712	.172
Seeding	4,311.334	1,016.375	.236
Weeding	....	....	....
Cutting (binder)	4,227.757	1,407.239	.333
Twine	3,744.207	1,082.380	.289
Shocking	3,901.137	428.305	.110
Stacking	2,814.768	1,516.979	.539
Stack thrashing (labor)	1,621.959	416.240	.257
Thrashing, cash cost	1,621.959	1,158.110	.714
Machinery cost	....	....	.558
Land rental	....	....	3.000
Total	....	....	8.389

Cost of Producing Spring Wheat—Fall Plowed—Continued.

Item	N. W. Minn.		
	Total Acreage, Five Years	Total Cost	Cost per Acre
Seed	5,196.833	$4,300.810	$0.828
Cleaning seed	4,965.968	147.571	.030
Plowing	7,186.027	8,120.460	1.130
Dragging	5,184.833	1,456.853	.281
Seeding	5,196.833	1,415.490	.272
Weeding	3,501.440	278.270	.079
Cutting (binder)	5,124.194	1,706.019	.333
Twine	3,041.414	593.200	.195
Shocking	5,124.194	690.165	.135
Stacking	2,448.241	1,177.160	.481
Stack thrashing (labor)	1,297.101	404.508	.312
Thrashing, cash cost	1,297.101	557.310	.430
Machinery cost			.371
Land rental			2.100
Total			6.977

LARGE FARM IN NORTHWESTERN MINNESOTA

Item	Total Acreage, Five Years	Total Cost	Cost per Acre
Seed	4,851.276	$4,501.205	$0.928
Cleaning seed	4,705.576	62.211	.013
Plowing	5,363.458	4,958.430	.924
Dragging	4,851.276	1,175.517	.242
Seeding	4,851.276	1,101.490	.227
Weeding	4,707.576	149.299	.032
Cutting (binder)	4,851.276	1,483.647	.306
Twine	4,851.276	919.530	.190
Shocking	4,851.276	614.420	.127
Shock thrashing (labor)	3,187.216	2,089.767	.656
Value consumed in thrashing outfit			.335
Machinery cost			.276
Land rental			1.800
Total			6.056

Cost of Producing Potatoes on Unfertilized Land.

Item	Clay County, Minn., 1907		
	Total Acreage, One Year	Total Cost	Cost per Acre
Seed (3,984 bushels)	331.643	$1,925.00	$5.804
Plowing	2,790.984	3,322.25	1.190
Harrowing	331.642	60.96	.184
Cutting seed	331.642	265.68	.801
Planting	331.642	205.68	.620
Weeding (horse weeder)	331.642	180.41	.144
Cultivating (three times)	331.642	920.54	2.776
Spraying (three times)	331.642	97.55	.294
Paris green	331.642	425.00	1.282
Bluestone	331.642	175.00	.528
Digging	331.642	443.88	1.338
Picking up 42,000 bushels, at 3½ cents per bushel and board	331.642	1,594.00	4.806
Hauling and storing	331.642	863.24	2.603
Machinery cost	....	....	.596
Land rental	....	....	3.000
Total	....	....	26.366

Cost of Producing Potatoes on Fertilized Land.

Item	Clay County, Minn., 1907		
	Total Acreage, One Year	Total Cost	Cost per Acre
Spring plowing	237.962	$241.90	$1.017
Harrowing (four times)	237.962	182.07	.765
Cost of seed (3,360 bushels)	237.962	2,016.00	8.472
Cutting seed	237.962	89.55	.376
Treating seed	180.250	21.60	.120
Corrosive sublimate	180.250	50.00	.277
Planting	237.962	163.97	.689
Fertilizers (25 tons)	100.000	650.00	6.500
Weeding (twice)	237.962	77.70	.327
Cultivating (three times)	237.962	431.73	1.814
Spraying (four times)	237.962	106.10	.446
Paris green	237.962	234.00	
Lime	237.962	42.00	1.833
Bluestone	237.962	160.00	
Digging	237.962	430.82	1.810
Picking up 38,300 bushels, 3½ cents bushel and board	237.962	1,513.80	6.362
Hauling, storing, and sorting	237.962	789.40	3.317
Machinery cost	....	....	.596
Land rental	....	....	3.000
Total	....	....	37.721

NOTE: These itemized cost accounts were collected on groups of Minnesota farms by very careful methods and show very good averages of the costs of farm operations pertaining to crop production. Land values and labor costs have risen appreciably since the date these figures were collected. The item of land rental is easily computed for any community by charging current interest on the market value of the land. Farm labor in these tables was computed from crop season wage rates averaging about $28.00 per month, exclusive of board furnished, which was worth on an average about $14.00 per month. Any increases in wage rates since the date of these statistics may easily be put into percentage increases, and approximate corrections made in these tables, if desired.

INDEX

(References are to pages.)

POPULAR FRUIT GROWING

By SAMUEL B. GREEN, late Professor of Horticulture and Forestry, University of Minnesota.
Revised by Le Roy Cady.

300 pages, 120 illustrations, cloth, $1.20.

Although there are a number of books on fruit culture extant, no other book is so thoroughly definite and explicit for the ordinary reader. In this volume every phase of Fruit Growing is discussed thoroughly with particular attention given to details.

The Appendix includes a complete spraying calendar with formulas for spraying and instructions how to apply and when; Fungicides and Insecticides; Waxes for Grafting and for wounds—how made; List of Fruits especially adapted to certain typical States; Rules for Naming Fruits; Usual Distances Apart for Planting Fruits; Also Number of Plants to the Acre.

VEGETABLE GARDENING

By SAMUEL B. GREEN, late Professor of Horticulture and Forestry, University of Minnesota.
12th Edition. Revised by Le Roy Cady.

252 pages, profusely illustrated, cloth, $1.20, postpaid.

This volume contains complete directions for the proper care and management of a farm or market garden. It is a thoroughly practical work, and is the result of the Author's many years of careful study and experience in vegetable growing. It is a work of incalculable value to farmers, truck gardeners and amateur vegetable growers, as well as a most complete text for students.

The immense sale of the former editions, which have been frequently revised, indicates the estimate of its value as a complete and thorough treatise of the subject.

For years Vegetable Gardening has been regarded as the leading authority.

The Appendix includes a Monthly Calendar of garden operations which is a valuable and safe guide for planting in the proper season. There are also many valuable tables of different data giving exact details.

AMATEUR FRUIT GROWING

By SAMUEL B. GREEN, late Professor of Horticulture, University of Minnesota.

134 pages, profusely illustrated, cloth, 60 cents.

A thoroughly practical guide to the growing of fruit for home use and the market. Written with special reference to colder climates.

Just the book for beginners, as it covers the entire subject of growth, cultivation and marketing of small fruits such as Strawberries, Raspberries, Blackberries, Currants, Gooseberries, Grapes, Cranberries, Juneberry, Sand Cherry, Buffaloberry and Mulberry in addition to the cultivation, pruning and grafting of the larger fruits such as the Apple, Plum and Cherry.

Every detail is explained clearly and nothing is left for the Amateur to assume.